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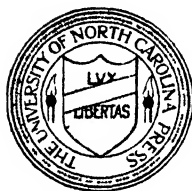
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THE GROWING AND PROCESSING OF WHOLE COTTON

BY FRANK K. CAMERON

WHOLE COTTON

*Definition.* The cotton plant, as with any other organism, can be forced to early maturity by crowding it during the adolescent or growing period. One does not obtain as fine an individual plant as when one follows the usual practice of wide spacing. Although the number of bolls on the individual plant may be smaller with crowding the number of plants per unit of area will be greater, and the total production of lint and oil will probably average as much as with planting in the usual way. With close planting, the plants mature within a period of 25 to 30 weeks after planting. There will be both mature and immature bolls, but the maximum weight of cellulose and of oil will have been reached, while the percentage of moisture will have closely approached the minimum. If the plants be cut now, they may be baled, and further drying proceeds without deterioration of the product.

Cotton so harvested is known as whole cotton. It consists of lint, seed, cusps, and stems. Most of the leaves are lost in the harvesting and baling. They constitute but two per cent. or less of the dried plants. They contain coloring matters, difficult to eliminate and the loss is advantageous. Seed cotton (lint and seed) comprises 60 per cent. of the mass of whole cotton, the remainder about equally divided between cusps and stems.

*The Purpose in Growing Whole Cotton.* Ordinarily, cotton is grown for the seed cotton, the rest of the plant being discarded as of no commercial value. From the seed cotton are recovered lint, linters, hulls, oil, and a meal, for each of which a market has been developed. The lint is nearly pure cellulose, but the cost of producing it is too high to permit it being used by the cellulose industries. Linters, or the short fibers cut from the seed after the lint has been removed by ginning, are likewise a quite pure cellulose, but the limited production and relatively high cost restricts its use to a few special products. The hulls removed from the seeds, before extraction of the oil, and the meal or press cake left after extraction are by-products, but the oil itself has an importance comparable to that of the lint (15).

Industrially, the growing of whole cotton is a very different enterprise, in purpose and method. It envisages the production of a *cheap* source of cellulose,

at the same time conserving the oil from the seeds. To achieve this purpose, planting, cultivating, and harvesting procedures are modified and in some details are actually different. The oil is extracted with a solvent instead of by a cold press. The processing of the residue for alpha-cellulose is quite different from the ginning and keir boiling of lint, and the end product differs markedly in physical characteristics, although essentially the same, chemically.

#### THE GROWING OF WHOLE COTTON

*The Seed Bed.* A well prepared seed bed is of the first importance. After a first preparation, it is desirable to give any weed, and grass seeds and roots time to germinate and start growth. A light but thorough discing or harrowing will then uproot them and they will be killed pretty completely if the weather be dry. The cotton can then be planted with assurance of establishing a stand without undue interference from foreign growths.

*Fertilizers.* On many soils an application of commercial fertilizers will be necessary to secure a satisfactory crop. Apparently, a generous application of a potassium salt is desirable. What mixtures and amounts would prove most desirable may be judged from the practice of the region. The common practice of a top dressing of sodium nitrate after the bolls commence setting is not justified, for a prolonged plant growth is not desired. If animal manures be used they should be disced or harrowed in when the seed bed is first prepared to give opportunity for the eradication of the weeds coming from the seeds in the manure.

*Varieties.* Seven or eight varieties have been grown for whole cotton, but not enough experience has been gained to justify a statement that any one of these is preferable. The variation in yield has been as great between separate plantings of any one variety as between the varieties themselves. Early maturing and prolific boll-bearing are the qualities most desirable, while size of individual plant and length of staple are of minor importance. A given variety will produce quite a different individual plant grown as whole cotton from what it would have produced if grown in the usual way. It will require time and the services of skilled plant physiologists to solve the problem of the "best" (12). Apparently, any variety known to be adapted to a locality can be used with good results.

*Seed.* Delinted seeds are to be preferred and with some mechanical planters they may be necessary. Our own experience is confined to seeds delinted by stirring them in concentrated sulfuric acid, a messy but not difficult job. Washed free of acid and air dried, they proved satisfactory in all respects. The Texas State Experiment Station has given much attention to delinting and delinted seeds are on the market.

*Planting.* Late planting is desirable some weeks later than is usual with cotton for the particular locality. The primary consideration is to have all weeds and objectionable growths so far developed that they can be completely eliminated with the preparation of the seed bed. If a following crop is to be planted when the cotton has been harvested, this must be considered in determining the date. That it is desirable to have a following crop admits of no

dispute, preferably one not requiring clean cultivation. A spacing of 4-6 inches between plants would probably be ideal but appears impractical with mechanical planting devices and 4 to 5 plants per foot have been the usual experience so far. Eight inches between rows has proved to be necessary to permit the passage of the cultivation tool and a greater width if tractor drawn cultivators are to be used. We have found 12 inches practicable. Broadcasting has been tried by Hall, at the Pee Dee Experiment Station near Florence, S. C., with some success, but experiments at the Dockery Farms in Richmond County, N. C., were failures, grass making a more rapid growth than the cotton. Attempted removal of the grass by harrowing tore up so much of the cotton that the experiments were futile.

*Cultivation* of whole cotton differs from that employed with cotton grown in the usual way in that no "chopping" or thinning of the plants in the row is called for. When the first cultivation should be made, is determined by the condition of the surface, the height of growth of the cotton plants and particularly by any invasion of grass and weeds. Commonly, a second cultivation seems called for, and in some cases a third. But this last may be unnecessary since the ground soon becomes shaded by the cotton plants, keeping the soil surface in good physical condition and inhibiting the growth of grass and weeds.

*Soil Character.* Much depends on the soil characteristics as well as the plant growth. In a recent experiment a planting on a rough stony soil, ill suited to cotton and difficult to cultivate, the cotton did not develop sufficiently over much of it to shade it and grass invasion was relatively bad. A mile away on a good average soil planted at the same time, the ground was completely shaded in a few weeks and a second cultivation amply met requirements.

#### HARVESTING OF WHOLE COTTON

The development of a plot of whole cotton has been followed, in a number of instances, by weekly or periodical laboratory analyses. It was found that the data obtained after 10 or 12 weeks' growth are significant. From then on the oil and cellulose content increased until about the 25th or 26th week they have attained their maxima, little or no percentage increase resulting from further growth. Ash and water content, on the contrary, have dropped to minima values which persist for several weeks longer. The individual plants carry 12 bolls, on the average, which are ripe or approach ripeness, with some further immature ones. Leaves are wilting and stems are hardening. Samples have been gathered by selecting an average plant from the plot at regularly placed intervals, quartering and making moisture determination as quickly as possible, while a dry sample was analyzed by standard methods.

Control by laboratory analyses would not be available to the practical grower ordinarily, but the appearance of the plants is sufficiently characteristic to determine when it would be time to harvest. Twenty-six weeks of growth is not regarded as determined arbitrarily. The "best" growing period may be modified by climate, season, soil, variety, cultural treatment or other factors and the judgment of the grower is no less important than in any other agricultural operation.

The first experiments on growing whole cotton were made at the Dockery

Farms near Rockingham, Richmond County, N. C. On this plantation was a gin, with baling equipment and storage space either under cover or on open platform. The cotton was cut with sickle or scythe, piled in small shocks for curing and then hauled to the gin. The next crop of cotton was cut with a hay mower, drawn by horse or by tractor and baled almost immediately in the field by a portable baler. The bales prepared at the gin house were of the dimensions of a standard bale of ginned cotton, but weighed well over 600 pounds a bale, while the bales put up in the field could be made to vary from 125 to 175 pounds, tied with wire as with hay, avoiding the use of straps and bagging. They were more convenient to handle and less expensive.

The cotton cut by the ordinary mowing machine gathered considerable amounts of earth and dust which persisted in adhering through the baling and subsequent operations. It was found later that this silicious material could be quite completely removed in processing but it would be better to avoid it. The John Deere Plow Company carried out an experiment with a tractor drawn assembly. A cutting bar immediately preceded an escalator upon which the cut plants fell with little or no contact with the ground. From the top of the escalator the plants fed into a hay baler, and the bales fell on a trailer. A very clean product was thus sent to storage. There was little or no "shattering" of lint from the bolls, unavoidable with the usual type of mower. The operators estimated that with this equipment the cotton can be harvested for 19 cents per acre. The International Harvester Company has independently given the same figure for harvesting with an assembly of their designing. The Hogan brothers have estimated that the cost of harvesting and storing should not exceed 20 cents an acre.

These assemblies can be readily disassembled and the component parts utilized for other purposes about the farm. The acreage covered in a given time would be the same as for hay and depend on the nature of the terrain and very much on the size and the shape of the field. Short rows requiring much turning of the equipment is the only serious obstacle to efficiency.

#### STORAGE OF WHOLE COTTON

Bales of whole cotton have been stored for 6 years both under cover and in the open and then found unharmed when broken open. But this same cotton after being extracted with organic solvents will "sour" or mold if left in water-moist condition, as with any plant residue. Twice, insects have invaded the stored cotton, but their depredations were confined to the pith in the stalks and had practically no significance for oil or cellulose content.

It appears settled that long time storage has no deleterious effect on the cellulose. So much is not claimed for the oil. No definite evidence has been found of loss or deterioration due to long storage, but the observations have been few. The necessity of removing coloring matter before or after extraction of the oil has prevented detection of hydrolysis or disintegration.

#### THE COST OF GROWING AND HARVESTING WHOLE COTTON

Mr. Nicholas W. Dockery (6) of Rockingham, N. C., who is responsible for much of the earlier laboratory work on whole cotton has had also more experi-

ence in growing it than any other individual. He has reported a cost of \$15 to \$16 per acre for growing and harvesting, omitting only an item for rent of the land. A "breakdown" of the figures into separate items involves, however, estimates, since the operations were carried on in connection with the large cotton plantings at the Dockery Farms. Milne (14) attempted detailed estimates from these and similar data concluding that they are probably truly representative of actual practice. In the spring of 1940, the International Harvester Company made a grant to cover the cost of operations in growing whole cotton, using only machinery methods. The co-operation of Mr. Don Matthewson, the County Agent for Orange County, was secured and the Hogan brothers carried out the operations four miles from Chapel Hill. Two plots were selected about a mile apart. One (North Plot) was a good average soil of the vicinity of the Cecil clay loam type. The second (South Plot) was selected largely as a contrast; it was very stony and proved to be ill adapted to machine operations. It was a Norfolk sand in type. Neither, so far as known, had ever been planted to cotton, but only to corn or grass. Half of each plot was planted in rows eight inches apart, the remainder in rows twelve inches apart. On May 19, the plots were harrowed and on May 22 they were planted, using a tractor drawn *Vegetable Planter*. No difficulty was encountered in planting the North Plot, but the stony, rough surface of the South Plot made it almost impossible to keep the tractor drawn seeder in line on a relatively large part of the area. The plants on both plots made a good start. A few and only light showers wet the plots between planting and harvesting. Corn, in the field adjacent to the North Plot, gave a very poor yield and that in the field surrounding the South Plot was a failure. Nevertheless, the cotton plantings made good progress and on the North Plot, so shaded the ground within three weeks that only an occasional foreign plant appeared. On the South Plot growth of the cotton plants was relatively slow after the first fortnight, never completely shaded the ground and there was a considerable invasion of crab grass; finally, nearly half of the plot was abandoned as not justifying the expense of cultivation. Apparently the bolls set sooner on the plants in the South Plot than in the North Plot, but a comparative count was hardly sufficient to justify a definite statement. Cultivation of both plots was made on June 10 with a tractor drawn *Vegetable Cultivator* and later with a *Rotary Hoe*. Probably two cultivations only, properly spaced as to time, would have sufficed for the North Plot. Because of an impending storm, the harvesting was several days earlier than planned and without waiting for the assembly to which reference has been made above. Hastily, the plants were mowed with horse drawn scythe, gathered with rakes and forks, baled in the field and hauled to a barn. In Table 1 are assembled cost data computed from the records of the Messrs. Hogan. Possibly all, and certainly some, of the items are higher than they would be on a larger scale operation better adapted to mechanized equipment. The items for mowing and baling are very far from the 20 cents an acre estimated as practicable.

A composite sample of the whole cotton from the three plots was analyzed and gave: total cellulose, 53.5%; oil, 8.4%; ash, 5.2% (mostly adhering soil); and water, 32.9%. Water and ash are unduly high.



It would seem that the Dockery estimate of \$15 to \$16 per acre has been justified. There remains to be added a charge for use of land, machinery, taxes, superintendence, etc., or say \$20 per acre *in toto*. But our concern is with the cost of a unit weight of whole cotton; and the yield per acre varied in ways that often appear inexplicable. We are quite unable to explain that in the experiment on the North Plot the acre planted to 12 inch rows gave nearly a ton and a half yield above the acre planted to 8 inch rows. However, with the experience so far attained, it seems safe to say that a yield of 5000 pounds per acre should be obtained readily and has been exceeded more often than not.

TABLE 1  
*Yields and Costs for Whole Cotton*

	NORTH PLOT		SOUTH PLOT
	8" rows	12" rows	12" rows
Preparing ground.....	\$0.60	\$0.60	\$0.60
Seed.....	2.75	2.75	2.75
Fertilizer.....	11.08	11.08	11.08
Planting.....	0.15	0.15	0.15
Cultivating.....	1.95	1.95	1.95
Mowing, baling and storing.....	3.40	6.00	1.60
Total operating costs.....	19.93	22.53	18.23
Rent of land.....	3.00	3.00	3.00
Total production costs.....	22.93	25.53	21.23
Whole cotton, pounds.....	4229	6978	3200
Whole cotton, cost per ton.....	10.84	7.32	13.27
Cellulose, pounds.....	2263	3733	1712
Oil, pounds.....	355	586	269

#### THE COMPOSITION OF WHOLE COTTON

Whole cotton may be regarded, conveniently, as a mixture of 20 per cent. stems, 20 per cent. cusps, and 60 per cent. seed cotton. Stems and cusps are wood, containing cellulose and the usual accompanying substances of ligneous growth. Seed cotton comprises lint, an almost pure alpha-cellulose, and seed meat surrounded by the hulls.

A mixture of waxes coats the lint and perhaps other parts as indicated by the fact that the de-leaved plant does not ferment before removal of the waxes. The hulls are said to contain 40 per cent. alpha-cellulose (1). The cellulose content of the seed meat alone has not been determined, but it has been for the whole seed. The seed meat is the source of cotton seed oil, a mixture of glycerol esters of unsaturated long chain paraffin acids. It contains also, to some extent, waxes. The processing methods are such that gossipol and other deleterious content of the seeds are excluded from the oil quite completely. The content of oil is about 8.5 per cent. of the air dried whole cotton.

The wood portions, stems and cusps, contain lignin which does not at present have any commercial significance and a small percentage of an aggregate including some highly colored substances. These last, unless they be first removed,

tend to accumulate in the solvent extract and make the refining of the oil a difficult task.

In addition to the oil, the commercially desirable component of whole cotton is cellulose; or, more properly, alpha-cellulose. It can be obtained from whole cotton by any of the procedures used in treating commercial woods, but there are definite advantages in the dilute nitric acid method (7).

The percentage of cellulose in whole cotton has been found to vary from about 45 to upwards of 55. This variation is to be expected since the proportions of stems to fruit is dependent upon variety, soil, seasonal and cultural vicissitudes, insect depredations, and the many factors affecting growth. In an exceptional case, when the whole cotton per acre reached the very large figure of 17 tons per acre, the production of cellulose per acre was about average although the percentage of cellulose in the plant was very low; the major portion of the crop was stems with comparatively few bolls. In general, with a good average crop, the content of cellulose will be above 50 per cent. It is not to be forgotten that, from the producer's viewpoint, it is the yield per acre that is significant, for it costs as much or more to bring a poor crop to harvest as it does a good crop.

The "total" cellulose as obtained by any of the procedures as yet proposed or used is not a pure product. Possibly in the plant itself, but certainly in the processing of it, there is some degradation and breaking of the large molecular aggregates. Hence, arbitrary methods have been devised for testing the cellulose. The sample of pulp or total cellulose is agitated in an aqueous solution containing 17.5 per cent. sodium hydroxide. That which does not go into solution or colloidal suspension is designated alpha-cellulose and it alone is of any present commercial value. From the mother liquor a precipitate is formed on the addition of a slight excess of acetic acid. This precipitate is designated as beta-cellulose, is not of itself commercially valuable, but its determination may be useful in judging the suitability of the pulp for certain purposes. The difference between the total pulp and the sum of the alpha- and beta-cellulose is called gamma-cellulose. Since the proportions of alpha-, beta-, and gamma-celluloses are generally held to be more or less characteristic of the origin, pulps have been prepared from delinted seed, cusps and stems as well as the whole cotton and the percentage of alpha-cellulose determined in each (6).

The results for the several pulps were: seeds, 83.3; cusps, 75.8; stems, 82.9; and for whole cotton, 97.3 (4). In an earlier study on less favorable material and different pulping procedure, the percentage of alpha-cellulose in five pulps was found to vary from 86.7% to 94% (10). From these figures there can be estimated the proportions of cellulose in whole cotton derived from the several components. The data are assembled in Table 2. From these data it would appear that the whole cotton would yield 45.6% total cellulose of which 89.5% is alpha-cellulose. Probably the percentage of lint has been estimated too conservatively, for an analysis of the whole cotton, from which these components were obtained, gave 53 per cent. total cellulose of which 93.3 per cent. was alpha-cellulose. The tabulated data indicate that 53 per cent. of the total and 59 per cent. of the alpha-cellulose in whole cotton comes from the lint.

Cellulose pulps prepared from wood contain other hydrocarbons, such as pentosans. For some uses, the presence of these may be desirable, but they are more often regarded as impurities and a standard method has been designed for estimating them. Inorganic constituents, or ash, should be and usually are low. With commercial pulps, the ash sometimes contains lime absorbed from the water supply. With whole cotton, the ash is mainly silica from adhering soil particles, which can be removed readily, when desired, in the process of pulping.

In addition to the composition of the pulp, the "copper number" and the viscosity of a suspension in cuprammonium solutions are determined by standard procedures, the data being regarded as indicative of the extent of degradation

TABLE 2  
*Distribution of Cellulose in Whole Cotton and in the Several Components*

COMPONENT	% OF COMPONENT	% TOTAL CELLULOSE FROM COMPONENT	% OF ALPHA-CELLULOSE FROM COMPONENT
Lint.....	24	24.0	24.0
Seed.....	36	5.6	4.1
Cusps.....	20	8.0	6.1
Stems.....	20	8.0	6.7

TABLE 3  
*Characteristics of Cellulose Pulps from Components of the Cotton Plant*

SOURCE OF PULP	STEMS	CUSPS	SEEDS	WHOLE COTTON
Alpha-cellulose.....	82.48%	82.34%	83.05%	84.21%
Beta-cellulose.....	1.10%	2.89%	3.21%	10.61%
Gamma-cellulose.....	16.42%	14.77%	13.74%	5.18%
Pentosans.....	8.78%	9.30%	14.81%	4.44%
Copper number.....	1.89%	2.07%	2.03%	1.15%
Cupra Ammonium Viscosity.....	14.4*	17.3*	21.1*	7.3*
Ash.....	0.93%	0.23%	0.18%	0.26%

\* Centipoise.

incidental to processing. In Table 3 are assembled the results of the determination of these characteristics for a sample of whole cotton and its components (7).

These data indicate that a pulp from whole cotton is comparable to commercial pulps from woods prepared by standard practices; and awaiting the pragmatic test of actual use, it must be considered as equally important.

#### PREPARATION OF WHOLE COTTON FOR PROCESSING

*Grinding.* The seed must be broken to permit effective contact of the oil with organic solvents. The stems and cusps must be reduced to small fragments for effective action of pulping solutions. Dockery found that the common form

of hammer mill used on farms for the preparation of cattle feed will pulverize satisfactorily dry whole cotton. A mill better adapted to the purpose was obtained later from the O. B. Wise Manufacturing Company of Knoxville, Tennessee. This mill is fitted with two screens; one with 0.26 inch openings, the other with 0.06 inch openings. The finer screen has seldom been found necessary nor particularly desirable.

The mill product is a fluffy mass, with harder particles imbedded or entangled in lint. *Apparently*, the lint predominates, although actually but a quarter in weight of the whole mass. A more or less efficient separation of the lint is possible by air elutriation during or subsequent to the grinding but that is not now considered desirable.

*Removal of Coloring Matter.* Dark colored substances may be extracted from the woody components of whole cotton by organic solvents or aqueous solutions of alkalis. Because of its high dispersing power, sodium sulfide is very effective. Warming the extracting solution increases its effectiveness and several repeated seepings will remove more or less completely the coloring matter. It has been found that a single seeping over night, in a two per cent. solution of sodium sulfide in sufficient volume to cover well the solid mass, gives a satisfactory result. The wet mass was thrown on a wire screen, the mother liquor pressed out and the residue washed twice with clean water. With each washing the water is removed as far as possible by pressing the mass on the screen. The effluent has the appearance of the "green liquor" in a Kraft pulp mill. The pressed residue will be sufficiently dry to be extracted with a low boiling paraffin oil (18).

#### THE RECOVERY OF COTTON SEED OIL

The physical characteristics of pulverized whole cotton precludes the extraction of the oil by pressing, which is the more common American practice when seeds alone are the source of the oil. Solvent extraction must be employed, a device which is now receiving much attention in the United States and which has long been common practice in Europe (18). All the common fat solvents have been found effective in extracting the oil. Because it is not flammable and is cheap, carbon tetrachloride has received much attention. But it decomposes on heating, corrodes metals, and "tenders" the cotton fibers, i.e. causing them to become brittle and easily pulverized. The most satisfactory solvent has proved to be a low boiling (70°C.-75°C.) petroleum oil. This solvent dissolves wax coating the lint, which is not itself objectionable; it would extract much coloring material from the stems and cusps, unless it be first removed as recommended above; it does not extract gossipol (16).

On recovery of the solvent by evaporation, a rather dark colored residue of oil remains. Some samples, on standing several days have deposited a small quantity of fluffy solid, which has not been identified. The oil, shaken with carbon black and filtered, yields a water white filtrate. A sample which has been exposed to the light for upwards of three years is yet entirely without color. In Table 4 are assembled, for comparison with the standards prescribed by the

American Oil Chemists' Society (2), the results of tests on a crude oil extracted from whole cotton which had not been pretreated with a solution of sodium sulfide, a crude oil from whole cotton which had been pretreated, and the refined oil prepared by shaking the second crude with carbon black and filtering (18).

Satisfactory oils have been obtained by decolorizing or "bleaching" the hydrocarbon extract, before volatilizing the solvent. There are advantages, apparently, in doing this; the yield of oil is larger.

TABLE 4

*Comparison of Characteristics of Oils from Whole Cotton with Standard Specifications*

	STANDARD SPECIFICATIONS A.O.C.S.	CONSTANTS DETERMINED FOR		
		Crude Oil from Whole Cotton	Oil from Na <sub>2</sub> S Pretreated Plant	Refined Oil from Na <sub>2</sub> S Pretreated Plant
Density at 25°C.....	0.916-0.918	0.885-0.890	0.893-0.900	0.908-0.912
n <sub>D</sub> at 25°C.....	1.468-1.472	1.475-1.479	1.474-1.476	1.473-1.475
Saponification Number.....	190-198	178	188	198-201
Iodine Number.....	106-113	88		101-105

#### COST OF RECOVERY OF OIL

Crude cotton seed oil is about 15.5 per cent. of the seed, and the average recovery of refined oil from crude is 92.5 per cent. in American practice (15). The prewar annual output in the United States was about 1,450,000,000 pounds, surpassed as an edible fat only by butter and lard. The residue from the refining is used for soap stock. The recovery of crude oil by solvent extraction in Europe yields a higher percentage; but the oil is more highly colored, and there would probably be some loss in weight and increased cost to bleach it to American standards. The crude oil obtained from whole cotton resembles closely that obtained in Europe from cotton seed.

It is conceded generally that the cost of equipment and installation of a mill for solvent extraction including solvent recovery would be no greater than for a press mill of the same capacity and that operating costs would be about the same. A mill to handle whole cotton may not be strictly comparable, because of the larger mass of material to be extracted.

For the decade preceding 1937 the average sale price for crude oil was 6.54 cents per pound, and was 7.86 cents for refined oil. For the past two years the figures have been above 10 cents for crude and 12 cents for refined, which reflects but is not accounted for by an increase in the price of seed.

Unfortunately, the available cost sheets of neither United States nor European mills disclose the cost of extracting the oil. Probably, it is less than 3 cents per pound. To this should be added the cost of raw material, and the usual fixed charges for interest, taxes, repairs and renewals, etc. But if present prices are to prevail, the spread between sales prices and production costs is more than sufficient to pay for the growing and harvesting of the cotton and the recovery

of the oil. The *practical* significance is that the degreased residue going to the pulping mill may be priced as low as the handling charge.

It is assumed, generally, that whole cotton would be grown primarily as a raw material for a pulp mill, and that oil would be recovered as a by-product. The question is posed, how far should a pulp mill be concerned in an oil mill? If the preliminary treatment to remove coloring matter be adopted, it would be advantageous to have the solvent extraction closely adjacent to the pulping operations. It might be desirable to ship the crude oil to a refining plant, as do some of the mills recovering oil by pressing. A recovery of oil by a pulping enterprise using whole cotton would be no more anomalous than the recovery of turpentine and resin by a mill using pine or tannins by a mill using spruce and hemlock.

#### PULPING WHOLE COTTON

Dried, ground whole cotton, which has not been degreased probably can be pulped satisfactorily. It has been done, tentatively, in attempts to recover the oil in the form of soaps from alkaline pulping liquids.

The degreased whole cotton is admirably adapted to pulping. Many pulps have been prepared by the sulfite, sulfate, and soda processes. Attempts to use these methods but without increased pressure, resulted in pulps which sometimes contained fragments of stems which were not thoroughly disintegrated. These fragments would disappear with "beating" of the pulp and could be avoided more or less completely by finer grinding or by seeping in an alkaline solution preparatory to extracting the oil.

In view of Pompilio's success with wheat straw (17), attempts have been made to pulp whole cotton with chlorine, but with unsatisfactory results. The time of treatment, temperature or pressure necessary to pulp the woody fragments of the stems and cusps resulted in marked degradation of the cellulose (13).

Satisfactory pulps have been obtained by treating whole cotton with a five per cent. aqueous solution of nitric acid, at atmospheric pressure. Although this reagent has been employed in the industry to a very limited extent as yet, it commands an increasing amount of attention and laboratory studies seem to be uniformly favorable to its use (7).

#### THE COST OF PULPING WHOLE COTTON

It has been noted above that after extraction of the oil, the residue of whole cotton could be delivered to the pulp mill at no cost other than a handling charge, and is, therefore, the cheapest possible source of cellulose. It must be expected, however, to carry part of the cost of its preparation. The economic or business data are not available on which to base a reasoned statement, other than that whole cotton can compete with any known source of cellulose.

Aside from the extraction of the oil, the principle item in the preparation of the whole cotton is the grinding, an operation costing no more than the barking and chipping of wood. The wood of the cusps and stems is easily pulped, and the amount of pulping reagents required is no more than for the usual woods.

Less bleach is required. High pressures not being necessary, degradation should be less. In consequence, the cost of producing a high grade cellulose from whole cotton can not exceed and should not equal the cost of production from any competing source.

#### CELLULOSE DERIVATIVES FROM WHOLE COTTON

Since degreased whole cotton is so readily pulped, attempts have been made to avoid or by-pass pulping, and make cellulose derivatives directly. Nitrates have been made readily, acetates with difficulty, but no success was achieved in efforts to make cellulose ethers (9). Admitting the possibility of more favorable results with larger sized experiments, the results indicate the economic desirability of first preparing the cellulose by a recognized pulping procedure.

#### USES OF CELLULOSE FROM WHOLE COTTON

The cellulose from whole cotton and from lint, stems, and cusps separately has been studied by means of X-ray techniques and found to differ in no way from the cellulose obtained from the commercially used woods (21). Dark field studies of the fibers with the microscope failed to show significant differences (5). Esters, ethers, xanthates, and dispersals in cuprammonium solutions, and alkali solutions, have been studied in comparison with like preparations from commercial celluloses, without essential differences being observed. It may be granted that the scale of the experiments is too small to carry conviction to the industrial expert. But they are an ample justification for the larger sized tests he may properly desire. It has been objected, that for certain uses, the variation in length of fiber in the cellulose from whole cotton would bar its use. This may be true, for certainly the cellulose from seed meats differs in fiber size from the cellulose from lint. It, however, comprises but a small fraction of the whole, and the mixture of fiber from lint, stems, and cusps seems to be no more diverse in character than the mixtures of linters and wood cellulose commonly used in the industry.

#### SUMMARY

The salient facts obtained in a series of studies in field and laboratory show the possibility of utilizing the cotton plant as a raw material for the production of oil and alpha-cellulose. We can have *available* a valuable, satisfactory and adequate raw material to supplement on the one hand our supply of fats and on the other hand to supplement existing commercial sources of cellulose. Before these conclusions can be accepted, it is evident that larger sized experiments must be made and preferably commercial or semicommercial trials by the pulp-ing industry.

The "unit" processes involved in the suggested processing of whole cotton for the recovery of oil and cellulose are all well established and no engineering difficulties are involved.

The suggestions advanced in this paper, do not imply that the growing of cotton for lint should be abandoned. There is little likelihood of this in any

foreseeable future, although there is general agreement that it should be restricted in the interest of the national economy. There are areas where cotton is now grown, but with scant hope of it ever being done profitably, where whole cotton might well offer economic advantages and could be substituted without too radical changes in the farmer's accustomed practices.

Finally, the growing of whole cotton for oil and cellulose, and the growing of cotton for lint and the usual by-products should be regarded as distinctly different industrial enterprises. The one point of contact is that both produce oil; and for this there is no prospect of a glut.

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# MITOSIS AND CELL DIVISION IN *PONTIGULASIA VAS* (LEIDY) SCHOUTEDEN

By A. B. STUMP

## PLATE 1

In a previous paper, the reproduction of *Pontigulasia vas* was briefly considered in relation to the materials needed for the test. The present work was undertaken to give a more complete description of binary fission in this representative of the *Diffugiidae*.<sup>1</sup>

### MATERIALS AND METHODS

The specimens of *Pontigulasia* used in this investigation were collected from a number of ponds in the vicinity of Charlottesville, Virginia, and the Mountain Lake Biological Station, Mountain Lake, Virginia. After identification the animals were isolated in Syracuse watch glasses with clean *Spirogyra*. These cultures were kept in moist chambers. By frequent changes of water and the occasional addition of fresh alga they were easily kept in good condition over the four or five days until used. The pH value ranged from 6.3 to 6.9 in these cultures. The temperature range was wide but this did not seem to be a critical factor as long as the changes were slow and the temperature did not rise above 20°C. A special effort was made to keep all such cultures free from sand or similar materials which could be used by the animals to form their shells.

When *Pontigulasia* are cultured without sand or other shell materials they are unable to divide (Stump, 1936): they will, however, form the peculiar pseudopods used to collect such materials. Animals with these pseudopods were found under the wide field binocular microscope and removed to separate dishes for close observation under the 16 or 8 mm. objective of the compound microscope. Finely powdered sand in water was then added and in a short time the animals would begin to collect it. At different stages in the collection and division these animals were fixed. It was found that animals about to divide, as well as those dividing, were very sensitive to movement or bright light and unless care was taken they would discard the sand and halt the division process. Although the shell of these animals and the mass of materials they collect obscure the processes of division to a large extent, it was possible to fix them at different mitotic stages with some accuracy. This was done by fixing the animals at various intervals from the time the collection of sand ceased.

Fixation was carried on with Bouin's, Schaudinn's, Carnoy-Lebrun and Allen's

<sup>1</sup> The greater part of this investigation was made possible by a fellowship at the University of Virginia and for this the author wishes to make grateful acknowledgement. The remaining work was carried on at the Mountain Lake Biological Station of the University of Virginia, Mountain Lake, Virginia, and at Flora Macdonald College, Red Springs, North Carolina. Thanks are also due to Professor B. D. Reynolds of the University of Virginia for his suggestions and assistance.

B 15 modification of Bouin's fluid. Bouin's and Allen's modification gave best results.

The sand grains of the shell of *Pontigulasia* make any examination of the internal structure almost impossible. Sectioning was tried as a solution to this problem but without success except in a few cases where the animals had been forced to use mica for their shells. Even here so many of the sections were lost that the process was given up. The method used in this work was to remove the silica ( $\text{Si O}_2$ ) of the shell, chiefly sand, by treating the fixed animals with 2% hydrofluoric acid ( $\text{H}_2\text{F}_2$ ) in 70% alcohol (Stump, 1936). Because the nucleus of these organisms lies in the center of a mass of cytoplasm containing many deeply staining bodies and food vacuoles, it was found best to embed the animals in paraffine after the acid treatment and then to section them. Embedding and sectioning were carried out in the usual manner except that most operations were done with the aid of a wide field microscope. The thickness of the sections varied between 7 and 15  $\mu$  in different animals.

A number of the usual stains were used, such as Heidenhain's iron hematoxylin, gentian violet, and Delafield's hematoxylin. Delafield's hematoxylin diluted one half to one third with water gave best results. It seems that the acid treatment had some effect on the staining reaction.

The effect of the acid on the fixation and staining was determined in two ways. First, by comparing the sections of the mica-shelled individuals already mentioned with those treated with the acid. Second, a large number of *Amoeba proteus* were fixed and divided into two lots. One lot was placed in 70% alcohol; the other in alcohol and acid. Both lots were then stained and mounted, using the same technique. This procedure was repeated, using various fixatives and stains. It was found that the acid had no appreciable effect on fixation but did change the staining reaction in that the usefulness of some techniques was lowered. This was particularly true in the case of Heidenhain's iron hematoxylin.

#### DESCRIPTION OF MITOSIS AND CELL DIVISION

The general organization of *Pontigulasia* in the resting condition is very similar to that found in *Diffugia* by Goette (1916), Pateff (1926), and others. The shell or test differs from that of *Diffugia* chiefly by the presence of an internal diaphragm between the neck and the fundus (Fig. 1-A). The mass of cytoplasm lies in the fundus of the shell with the pseudopods extending through the diaphragm and neck to the exterior. This cytoplasmic mass contains numerous spherical bodies ranging from 1 to 6  $\mu$  in diameter. Some of these are food vacuoles while others are of an undetermined nature. The number of these bodies varies greatly in different animals. There are also contractile vacuoles present, usually lying in the outer part of the endoplasm near the diaphragm. The nucleus of *Pontigulasia vas* is vesicular in type. It is almost spherical in shape with a diameter ranging from 18 to 20  $\mu$ . Within the distinct nuclear membrane are found 15 to 25 deeply staining endosomes. Most of the endosomes lie near the nuclear membrane but some are scattered within the interior

(Fig. 1-B). Forming a background for the endosomes is a more or less diffuse net of lightly staining material. When closely observed this net is seen to be composed of irregular ribbon-like strands, many curved and branched. There are a few granules scattered on the net, but taken as a whole it is not granular in composition. See Fig. 1-A. Most, if not all, of the chromatin of the resting nucleus is in this structure.

For approximately four hours preceding division the animals collect materials for the new shell. The pseudopods during this period are large and irregular in outline, with a wide hyaline area at the ends. Movement is very active at the beginning, and the shell is often held in a vertical position. As the sand grains are seized by the pseudopods, they are passed back toward the mouth of the shell. Grains of all sizes small enough to be moved are thus indiscriminately added to those collected in a mass just in front of the mouth. As the animal moves about, most of the large particles collected early in the process are lost. Thus most of the grains close to the mouth tend to be small. Later the movements become much slower and the larger pieces will be held. As will be seen, this arrangement will affect the position of the sand grains in the completed shell. It appears unlikely that more than a few of the smallest grains are taken inside the mouth. During the collecting period the nucleus remains unchanged. Following the collecting period the pseudopods are withdrawn, and there is a short time of inactivity marking the onset of nuclear changes.

*The Prophases.*—The early prophases begin with the end of pseudopod formation. The nucleus is enlarged and the endosomes show a slight swelling (Fig. 2-A and B). The net of lightly staining material has now somewhat contracted so that it is darker and more thread-like, though still irregular and often disconnected. There is an increase in the size and number of granules on the net. In a few examples of very early prophase the net tended to form more in the center of the nucleus, leaving a clear area next to the nuclear membrane. This resembles closely the situation found by Pateff (1926) in *Disflugia pyriformis*. At about the same time as the onset of the prophases, the cytoplasm becomes highly vacuolated (Fig. 3-A). This animal had not yet started formation of the new shell although the nucleus is in middle prophase. Note that the fundus is almost completely filled with cytoplasm and a large mass of it projects from the mouth of the shell. Before treatment with the acid, the part projecting was completely covered with sand grains. As a rule, by early prophase the shell formation is well advanced. The formless mass of cytoplasm outside the shell takes on a bubble shape which extends out from the mouth. Once started the bubble enlarges rapidly and the sand grains arrange themselves over the surface as it forms. As Rhumbler (1898) has suggested, the orientation of these grains is probably due to surface tension on the cytoplasmic membrane. This first swelling forms the fundus of the new shell and takes place so that the outer sand grains, collected last, cover this surface. The grains collected earlier are left as a sort of collar about the mouth of the old shell. After a pause the neck is formed, pushing the fundus outward. As this takes place, the neck is covered by the materials of the collar mentioned above. Thus the sand grains

are arranged on the new shell so that the large ones cover the fundus, while the neck is composed of smaller ones. So rapid is this process of shell formation, 15 to 20 minutes, that by middle prophase the new test is usually complete except for the cement which will hold the grains together. At this point the two shells lie mouth to mouth. Fig. 2-A shows a section of an animal at the end of the shell-forming process except for a small part of the neck of the new test. The cytoplasm in the fundus of the old shell is somewhat contracted over that seen in Fig. 3-A, while the cytoplasm outside the mouth of the shell has enlarged and taken definite shape. The many small vacuoles seen in the earlier stage have given way to a few large ones, particularly in the area where the fundus of the new shell will be located. This is the bubble of cytoplasm mentioned above.

In middle prophase there is little change in the cytoplasm and its role in shell formation; the processes already started in early prophase are continued. As has been noted, the animal shown in Fig. 3-A was not typical, in that development of the test had lagged behind the nuclear changes. Nuclear changes in middle prophase are marked over those in the previous stage. The size of the nucleus has increased and the endosomes are swollen and highly vacuolated. The net now is well developed as definite strands with the chromatin granules collecting on them in clumps. In some sections these strands seem to radiate out from the center of the nucleus as in Fig. 3-B; other nuclei at this stage show the strands of the net extending across or radiating out somewhat from one point near the periphery (Fig. 3-C), depending on the position of the nucleus. In middle prophase the nucleus has reached its maximum enlargement.

By late prophase the formation of the shell for the daughter animal is finished except that the sand grains are only lightly cemented together. The cytoplasm appears to be but little changed from the earlier stages though there are fewer vacuoles. Fig. 4-A shows the cytoplasmic features of an animal in this stage. The nucleus in late prophase has begun to shrink and at the same time the clumping of the chromatin in the beginnings of an equatorial plate can be seen. The endosomes are present in this stage, particularly the ones close to the nuclear membrane, but they are small and seem to be disintegrating. See Fig. 4-B. The strands of the net, so clear in middle prophase, are difficult to observe in some cases.

The total time for the prophases averaged 48 minutes with extremes at 40 and 70 minutes. This is much slower than for *Amoeba dubia* as reported by J. A. Dawson, Walter R. Kessler, and Joseph K. Silberstein (1935), or for *Amoeba proteus* by Chalkley and Daniel (1933). Early and middle prophase occupied most of the time; the later stages being quite rapid.

*Metaphase.*—The cytoplasm in metaphase continues to resemble that of the prophases in most respects. The fundus of the new shell is filled with it, and there is a long pseudopod-like mass extending back to the ball of cytoplasm in the old test. Sections made at this time, such as seen in Fig. 5-A, show that the cement between the grains of the new shell is well formed. The character of this cement was not investigated but according to most authorities in

similar forms it consists of chitin or pseudochitin (Awerinzew, 1909; Zuelzer, 1904). The metaphase nucleus shows a marked decrease in size and as a result the nuclear membrane is wrinkled. The membrane, however, remains unbroken. The position of the nucleus is in the center of the cytoplasm of the old shell, having moved toward the mouth from the preceding stages. Fig. 5-B shows the nucleus of Fig. 5-A in more detail. There is a well formed equatorial plate with 8 to 12 chromosomes lying on the spindle fibers. These chromosomes, while relatively large, appear to have a number of granules associated with them on the spindle so that they are not clearly defined. Under careful inspection the chromosomes seem to be granular in nature also. The endosomes present in the nucleus are vacuolated but less disintegrated than those of late prophase. The large endosome that appears to be lying partly outside the membrane is in a wrinkle and is included in the nucleus. No centrioles were observed. The oblique angle of the equatorial plate to the longitudinal axis of the animal is typical of sections made of individuals in metaphase, or, in some cases, late prophase. Ivanič (1934) found a similar condition in two species of *Euglypha*. This, he considered, indicated a transition stage from longitudinal to transverse division. Metaphase is of very short duration, lasting only about 5 minutes.

*Anaphase.*—No stages of early anaphase showing actual splitting of the equatorial plate were secured. Fig. 6-A shows a section of an animal in anaphase shortly after the chromosomes had separated. The cytoplasm is considerably contracted in the new shell, leaving it partially empty. In contrast to most previous stages, the cytoplasm is almost free from vacuoles. This individual had a large number of the dark staining bodies in the area surrounding the nucleus. The nucleus has now taken on an elongated shape, but its axis continues to be oblique. The nuclear membrane, while thin and slightly twisted, remains unbroken. The chromosomes have separated and moved poleward on the spindle, as can be seen in Fig. 6-B. Like the metaphase, these chromosomes have granules associated with them on the spindle fibers, though in general they are more clearly defined. Eight chromosomes can be made out on each side of the split plate. The endosomes have disappeared by this stage and will not be seen until the nucleus is reorganized. The role of the endosomes in mitosis of these animals is not clear. It does not seem likely they have any chromatin and probably consist largely of plastin material. Anaphase occupies a shorter time even than metaphase, certainly less than 5 minutes.

*Telophase.*—Shortly after the nucleus divides within the fundus of the old shell, there is a movement of the cytoplasm back into the new one so that sections made at this time are somewhat like the prophases. Fig. 7-A is a drawing of two animals just after the nuclei have separated. The nucleus of the parent individual is clearly seen, while that of the daughter does not show in this section. A number of the dark staining bodies associated with the cytoplasm around the nucleus can be seen in the new animal. Evidently they were carried over into the newly formed shell by the same movement of cytoplasm that separated the nuclei. Some of these bodies can be seen in the area connecting the two animals.

No sections of this stage showed the nucleus greatly elongated, and from the material at hand it appears that marked nuclear elongation does not occur. Fig. 7-B shows one of two nuclei which were near each other in the cytoplasm of the old shell and had evidently just separated. This nucleus is very small, with the chromosomes still in a form like the split plate seen in the anaphase, but less granular and more distinct. The spindle has entirely disappeared. By the time the nuclei have separated into the two animals, the chromosomes lose their identity and form a mass of granular material in the center of the nucleus. This is shown in Fig. 7-C. The nucleus has enlarged and around the periphery has appeared a rim of dark material which later forms the endosomes. At about this stage a flowing back and forth of the cytoplasm begins; the movement taking place between the two animals as they lie with their shells mouth to mouth. For the next 10 to 15 minutes this movement continues and ends only when the cytoplasm is divided between the two individuals. Pateff (1926) describes a similar cytoplasmic movement in *Diffugia mammillaris*. By this time the nuclei are in the reconstruction stage, as shown in Fig. 8-A. The cytoplasm is now concentrated in the fundus of both shells, fairly evenly divided as to volume and the number of the dark staining bodies in each individual. Details of the nucleus are shown in Fig. 8-B. Besides having enlarged considerably, the nucleus has regained its spherical shape. The chromatin granules are scattered over the nucleus on a net and are still large. The endosomes have reappeared around the inside of the nuclear membrane, though yet small in size. With the exception of the granules and the thread-like net, the reconstruction nuclei are much like the resting form. Soon after the separation of the cytoplasm the two animals will form pseudopods and move apart, thus ending the process. The duration of the telophase was between 15 and 25 minutes on the average, with somewhat more variation than the other stages.

The total time for mitosis averaged 1 hour and 20 minutes. The shortest time for the process was 1 hour and 2 minutes, the longest 1 hour and 40 minutes.

#### DISCUSSION

The similarity between division in *Pontigulasia vas* and that described for related forms makes a detailed comparison unnecessary. There are, however, some points worthy of discussion.

In *Diffugia mammillaris* and *D. pyriformis*, Pateff (1926) found that the granules and the net of early prophase arose from materials of the outer nucleus. The net and the granules of the resting nucleus break down before the prophase structures appear. In *Pontigulasia* there is some evidence that the net of lightly staining material scattered over the resting nucleus becomes the more definite structures of the prophases.

As has been mentioned before, the role of the endosomes in *Pontigulasia* during mitosis remains in doubt. The fact that they are present after the equatorial plate has been formed, and that they begin to reappear while the chromatin is still concentrated in the center of the telophase nucleus, supports the view that they have no important part in mitosis as far as the chromatin and the net

are concerned. It was because of the uncertain part played by these nuclear bodies that the term endosome has been used (Calkins, 1933).

The small number and definite outlines of the chromosomes in *Pontigulasia vas* are different from the condition described for the two species of *Diffugia* by Pateff (1926). The chromosomes of *Pontigulasia* are formed by the concentration of the chromatin granules of the early prophase. By metaphase the chromosomes have been formed, but they are granular in structure and they have many granules with them on the spindle. Though sections showing splitting of the entire metaphase plate were not secured, there is some evidence that a longitudinal division of the chromosomes occurs. This is shown in Fig. 5-B, where one or two of the chromosomes appear to be splitting in this way. In the anaphase some pairing may be seen, and this too would seem to support a similar view. The granules on the spindle fibers present another problem, but there is little or no evidence to indicate what happens to them. In early telophase the chromosomes are clearest and appear least granular. Evidently the granules associated with the anaphase chromosomes have now fused with them, or less likely, they disappeared with the spindle fibers. As far as could be determined, the nuclear membrane remains unbroken during the whole process of division.

The time intervals given for the different stages are open to some question, because it proved almost impossible to control the temperature during division. Low temperatures tended to retard the process, but as a whole the optimum temperature was well below that reported for *Amoeba proteus* by Chalkley and Daniel (1933) and Liesche (1938) or for *Amoeba dubia* by Dawson, Kessler and Silberstein (1935).

During the course of this work a few large cultures of *Pontigulasia* were kept under observation for two to three months at a time. If these cultures were allowed to get in poor condition due to overcrowding, lack of food, or failure to change the water occasionally, a kind of plasmogamous union took place between the animals. Usually this took place in pairs, but occasionally a number of individuals would associate together. On investigation this fusion was found to be a cytoplasmic one only. No spores or gametes were noted. Inactive stages were seen but these were of a temporary nature, the mouth of the shell being filled with a plug of mucous or detritus material, and without the formation of a cyst wall.

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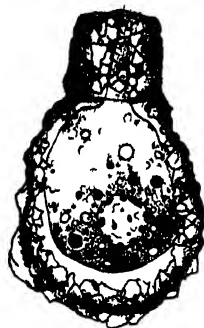
## EXPLANATION OF PLATE 1

All figures, with the exception of 1-A, were drawn with the aid of a camera lucida from sectioned material.

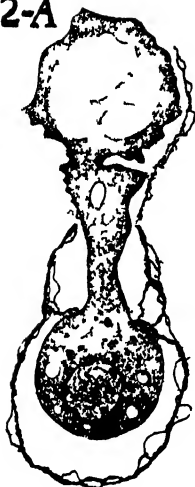
- Fig. 1-A. Diagrammatic drawing of *Pontigulasia vas*. Part of the shell has been omitted to show internal structure.  $\times 400$ .  
B. Section of a resting nucleus.  $\times 800$ .
- Fig. 2-A. Early prophase. Formation of the new shell is well advanced.  $\times 400$ .  
B. Details of the nucleus shown in Fig. 2-A.  $\times 800$ .
- Fig. 3-A. Middle prophase, but shell formation has hardly started.  $\times 400$ .  
B. Nucleus in middle prophase.  $\times 800$ .  
C. Nucleus in middle prophase.  $\times 800$ .
- Fig. 4-A. Late prophase. The new shell is almost complete. Note the constriction in the cytoplasmic mass; this marks the position of the diaphragm.  $\times 400$ .  
B. Details of the nucleus.  $\times 800$ .
- Fig. 5-A. Section of an animal in metaphase.  $\times 400$ .  
B. Details of the nucleus.  $\times 800$ .
- Fig. 6-A. Anaphase. The outlines of both shells are almost complete.  $\times 400$ .  
B. An enlarged view of the nucleus of Fig. 6-A.  $\times 800$ .
- Fig. 7-A. Telophase. Only one nucleus appeared in this section.  $\times 400$ .  
B. Details of a nucleus in early telophase.  $\times 800$ .  
C. Late telophase.  $\times 800$ .
- Fig. 8-A. A section of two animals shortly before separation.  $\times 400$ .  
B. Details of the reconstruction nucleus of Fig. 8-A.  $\times 800$ .

PLATE 1

1-A



2-A



3-A



4-A



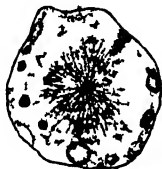
1-B



2-B



3-B



3-C



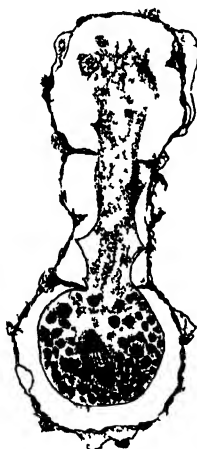
4-B



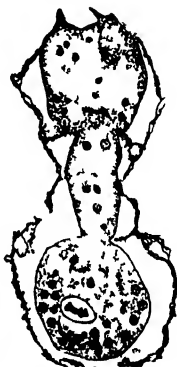
5-A



6-A



7-A



8-A



6-B



7-B



7-C



5-B



8-B





# THE EFFECT OF ADRENOCORTICOTROPIC HORMONE ON THE INTERRENALS (CORTICAL TISSUE) OF TRITURUS TOROSUS

BY CLAUDE A. VILLEE, JR.

The anterior lobe of the hypophysis is known to produce many different hormones (Evans, 1935; Collip, 1934a, 1934b), among which are the growth-promoting, gonadotropic, lactogenic, thyrotropic, diabetogenic, ketogenic, and adrenocorticotropic.

The first connection between the pituitary and the adrenal was noted by Brown (1920) who showed that extirpation of the thyroid and pituitary anlagen in *Rana pipiens* produced atrophy of the interrenal tissue. Several observers have reported that hypertrophy of the adrenal cortex follows administration of anterior pituitary extracts. Evans (1924) noted that the adrenal cortex was sometimes hypertrophied in his hyperpituitary giant rats. Reiss and Langendorff (1929) found enlargement of the adrenal in one of their dogs treated with a pituitary extract. Hypertrophy of the adrenal cortex following treatment with anterior pituitary extract was observed by Emery and Atwell (1933) in albino rats. Anselmino, Hoffman, and Herold (1933, 1934) made a very specific extract of the anterior pituitary which produced hyperplasia and hypertrophy of the adrenal cortex of female mice. Fat inclusions, which are normally found only in the zona fasciculata, were found in all three layers of the adrenal cortex after treatment with the extract. The glomerular zone was found to be twice as thick as normal. They found that a young male mouse was most sensitive to stimulation by the extract. Houssay, Biasotti, Mazzocco, and Sammartino (1933) also noted hypertrophy of the adrenal cortex in dogs after treatment with anterior pituitary extract. Loeser (1933) found hypertrophy of the adrenal after administration of thyrotropic extract to normal animals but not in thyroidectomized animals. Emery and Winter (1934) using anterior pituitary extracts, and McQueen-Williams (1934) using pituitary implants, failed to obtain hypertrophy of the adrenal cortex in thyroid-parathyroidectomized rats. Winter and Emery (1936) found that thyroidectomy does not affect the degree of compensatory hypertrophy which normally follows the removal of one adrenal. Atwell (1935) using a purified adrenocorticotropic extract of Collip, Anderson, and Thompson (1933) produced marked hypertrophy of the adrenal cortex and an increase of the osmiophilic content of hypophysectomized frogs. Atwell (1937) administered adrenocorticotropic extract to tadpoles of *Rana pipiens* and *Rana sylvatica* which had been hypophysectomized and thyroidectomized and produced hypertrophy of the atrophic adrenal glands and great increase in their osmiophilic content without any effect on the thyroid, showing that the action of the adrenocorticotropic hormone is not mediated through the action of the thyroid. Moon (1937) used a purified extract of adrenocorticotropic hormone to set up a method of biological assay of the extract. He obtained restoration of the cytoplasm of the cortical cells of the adrenals of hypophysectomized rats. The nuclei were no longer pycnotic and there was an increase in

the fat content of these cortical cells following the administration of an extract very similar to the one used in this study.

#### MATERIALS AND METHODS

Twenty adult *Triturus torosus*, each at least two or three years old, were collected from Wildcat Canyon, Contra Costa County, California. An extract of adrenocorticotrophic hormone "containing some lactogenic and other residues as impurities" was obtained from Dr. Lyons of the Department of Anatomy, University of California. It was labeled L248I and was prepared according to the method devised by Lyons (1937). It contained 2.5 mg./cc. solid (active) material. This was injected subcutaneously into the lymph spaces beneath the chin and in the groin and axilla of the experimental animals.

The newts were kept in separate refrigerator dishes 5" x 5" x 2½", in which water was placed and changed frequently. They were fed ground beef, liver, and mealworms.

The cortical tissue of the adrenal in *Triturus* is scattered in discrete patches along the branches of the renal arteries and veins on the ventromesial surface of the mesonephroi. It appears macroscopically as small orange-yellow clusters of cells around the blood vessels, especially frequent near their points of branching. There are at least forty such clusters of interrenal cells along the ventral side of the mesonephroi and several other clusters more anterior, along the course of the posterior vena cava.

In analyzing the effect of the injections of the extract, the entire mesonephros was removed together with the interrenal patches on its ventromesial surface and fixed in ten per cent formol for several days. The tissue was then washed in water and cut in frontal sections ten micra thick using the freezing microtome. These sections were dipped in 70 per cent alcohol momentarily, stained in Scharlach R ten minutes, placed in 70 per cent alcohol again for about ten seconds and then transferred to water, where the surface tension effect helped to spread them nicely. The sections were mounted in glycerine for study, and the cover slips rimmed with Euparal. The adrenals appeared as islands of cells containing droplets of lipid material which stained red with Scharlach R in the mass of mesonephric tubules.

#### EXPERIMENTAL OBSERVATIONS

Fifteen of the twenty adult *Triturus* were used as experimental animals; the other five were reserved as controls. Table 1 gives the amount of extract given to each animal, the daily dose, the number of doses, and a comparison of the total dose with the body weight. All the animals in the experimental groups showed stimulation of the cortical tissue. The droplets of lipid secretory material were both larger and more numerous in the experiment animals than in the controls. In general the amount of stimulation as estimated by a study of the comparative size and number of the lipid droplets was proportional to the amount of hormone injected per gram body weight, although there are several deviations from this. There was no distinct evidence of hypertrophy of

the gland, but there was some evidence of hyperplasia in the animals most greatly stimulated.

Some very young *Triturus* had previously been injected with the extract in amounts varying from .03 to .15 cc. daily. It was found impractical to use animals of this age because they are apparently too sensitive to the extract, most of them dying within a short time even with the minimal dose. In addition, the adrenals are so small at this stage that in sectioning the mesonephros the few sections on which the adrenals were present were frequently lost.

The extract seemed to show some thyrotropic activity also, since the experimental animals moulted more often than did the controls. Moulting has been shown to be controlled by the thyroid in *Triturus* by Adams and Richards (1929).

Dr. Lyons has shown (unpublished data) that this extract will stimulate the adrenal cortex of twenty-eight day rats with a minimum threshold of about

TABLE 1

ANIMAL	DAILY DOSE, CC.	NUMBER OF DOSES	TOTAL DOSAGE		BODY WEIGHT, G.	MG./G.	AMOUNT OF STIMULATION
			In cc.	In mg.			
1	.10	11	1.10	2.75	12.5	.22	***
2	.10	6	.60	1.50	10.5	.14	***
3	.10	3	.30	.75	11.8	.06	**
4	.10	2	.20	.50	9.7	.05	*
5	.20	3	.60	1.50	13.8	.10	*
6	.20	3	.60	1.50	12.7	.12	**
7	.20	4	.80	2.00	11.4	.17	**
8	.20	4	.80	2.00	12.2	.16	**
9	.50	2	1.00	2.50	13.4	.18	***
10	.50	2	1.00	2.50	10.5	.23	***
11	.10	3	.30	.75	11.5	.06	*
12	.10	3	.30	.75	11.5	.06	*
13	.10	2	.20	.50	11.2	.04	*?
14	.20	2	.40	1.00	11.4	.09	*
15	.20	2	.40	1.00	10.9	.09	*

.30-.40 mg. hormone per gram body weight of the rat. This study showed that the minimum threshold for *Triturus* was about .06 mg. hormone per gram body weight.

## SUMMARY

1. The interrenal tissue of *Triturus torosus* was shown to be stimulated by an extract of adrenocorticotrophic hormone from the anterior lobe of the sheep pituitary.

2. *Triturus* adults are more sensitive to the extract than are twenty-eight day rats, the minimum threshold for *Triturus* being .06 mg. hormone per gram body weight, for rats, .30-.40 mg. hormone per gram body weight.

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# RARE CYCLOPOID COPEPODS FROM WELLS IN NORTH CAROLINA

BY HARRY C. YEATMAN

## 25 TEXT FIGURES

Early in November 1942, Mr. John M. Geary of the Orange-Person-Chatham District Health Department, Chapel Hill, N. C., brought to Dr. R. E. Coker in the Wilson Zoological Laboratory some copepods from a well in Chatham county. The copepods appeared to be of a form not previously known in this region and were given to me for further study. They proved to be examples of *Cyclops bicuspidatus navus* Herrick—a form we have long sought in this region. This find suggested exploration of a previously neglected habitat and Mr. Geary kindly took me to various wells in Chatham and Orange counties. I am greatly indebted to him for the opportunity to make this preliminary study conveniently as well as for assistance in the operations of collecting. I wish also to express appreciation to Dr. Coker for helpful suggestions in the preparation of this paper.

## METHODS

Two weighted 12-inch plankton nets were used alternately at the wells and washed after each use to prevent mixing of collections. The net was simply lowered to the bottom, allowed to remain there a few seconds and then quickly raised. Microcrustacea entering the net would be washed into a bottle secured in the bottom of the net. The pH records are given as taken in the field with Hellige comparator.

All collections were made on November 25, 1942, except those made by Mr. Geary, November 4th and 5th, 1942, at the Wilkie Farm (station No. 4).

## LOCATION AND DESCRIPTION OF WELLS

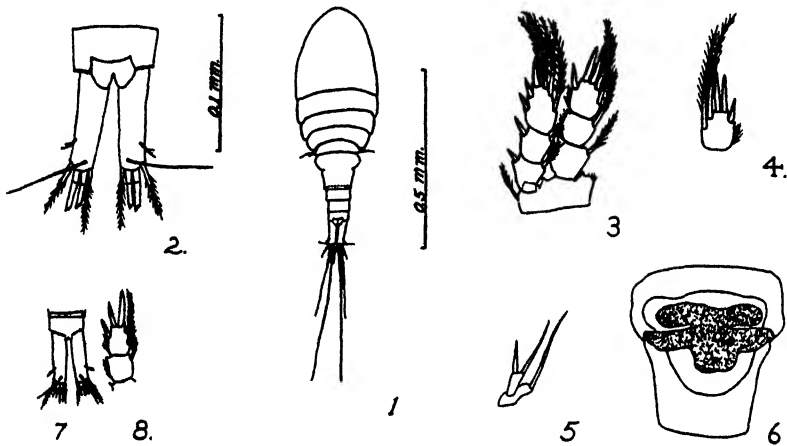
Station No. 1. Well at the home of Clarence Powell about 200 yards south of the Orange-Chatham county line, on the right side of U. S. 15-501 going towards Pittsboro, N. C. Top of well protected by wooden structure with a wooden door; water about 40 feet below surface of ground, but only a few feet in depth; pH 6.2. The rare *Cyclops crassicaudis brachycercus* Kiefer was found abundantly in this well. Hitherto it has been found in this region at only one place; see below, p. 30.

Station No. 2. Well at Lystra Church about 3 miles south of Orange-Chatham county line and about  $\frac{1}{2}$  mile east of U. S. 15-501. Well-top protected as in Station No. 1; water about 50 feet below surface of ground and only a few feet deep; pH 5.8. No copepods were taken by our nets.

Station No. 3. Well about 1.5 miles north of Farrington, N. C. Follow road past Lystra Church to T-junction; turn right to first house on left. Well top is of wood, as usual; water about 7 or 8 feet below surface of ground and only about 3 feet deep; pH 5.8. Copepods closely resembling the very rare *Cyclops nearcticus* Kiefer were fairly common.



Station No. 4. Well at farm of Bernice A. Wilkie about 12 miles east of Pittsboro, N. C., and at the end of a short dirt road north of U. S. 64. Well-top reinforced with brick and cement and enclosed in a screened porch; water about 42 feet below surface of ground and about 7 or 8 feet deep; pH 6.8; well dug in 1917. It was from this well that Mr. Geary's first collections were made, November 4 and 5; but the well had been chlorinated shortly before our collections were made, and we found no copepods. The original collections yielded many *Cyclops bicuspidatus navus* Herrick and several *Cyclops varicans rubellus* Lilljeborg.<sup>1</sup>



All figures are original camera lucida drawings unless otherwise stated.

FIGS. 1-8: *Cyclops nearcticus* Kiefer

Fig. 1. Adult female from Chatham County, North Carolina.

Fig. 2. Dorsal view of furcal rami and last abdominal segment.

Fig. 3. Fourth foot.

Fig. 4. Terminal segment of endopod of 4th foot.

Fig. 5. Fifth foot.

Fig. 6. Seminal receptacle of an anesthetized female.

(Figs. 2-6 drawn to the same scale.)

Fig. 7. Ventral view of furcal rami and last abdominal segment. After Kiefer, 1934.

Fig. 8. Second and third segments of endopod of fourth foot. After Kiefer, 1934.

Station No. 5. Well about  $\frac{1}{4}$  mile south of Wilkie Farm (station No. 4) and on the same dirt road. Well with the usual wooden top; water about 25 feet below surface of ground and only a few feet deep; pH 6.2. *Cyclops crassicaudis brachycercus* Kiefer was found to be common. A few isopods (unidentified) were present.

Station No. 6. Well about 2 miles from U. S. 15-501 on the road from Pittsboro to Moncure, N. C. Well is on right side of road under an oak tree by an

<sup>1</sup> Three months later, collections in this well by Mr. Geary and Miss Ruth Naylor revealed the presence of copepods in this previously chlorinated well: two nauplii and one adult male identified provisionally as *C. bicuspidatus navus*.

unpainted frame house with two rows of boxwood. Top of well protected by the usual wooden structure, but with door of large-mesh wire-cloth instead of wood; water about 25 feet below surface of ground and only a few feet deep; pH 7.0. *Cyclops bicuspidatus navus* was very abundant. There were more copepods in this well than in any other.

Station No. 7. Well at Haywood School on U. S. no. 1, about  $1\frac{1}{4}$  miles east of Moncure and 100 yards west of Haw River. Part of the wooden cover missing; well enclosed in a lattice house; a large terra cotta pipe extending deep into the well; water about 50 feet below surface of ground and at least 10 feet deep; pH 6.2. At the time of our collection, the well was condemned and locked because of the presence of *Bacillus coli*. Although this well contained much debris, including caterpillar feces, no copepods were present.

Station No. 8. Well across road from New Elam Christian Church about 2.5 miles north of U. S. no. 1. Well-top with large terra cotta pipe extending about 3 feet above ground; protected by a roof; water about 25 to 30 feet below surface of ground and only a few feet deep; pH 6.0. One male *Cyclops bicuspidatus navus* Herrick was found, but, since this copepod soon died and no others were collected, I believe this example had been retained in the net, despite washings, from our collections at station No. 6.

Station No. 9. Well at deserted frame house 2.7 miles from Wilson Zoological Laboratory on U. S. 15-501 by sign designating a curve. House and well on left side of road going towards Chapel Hill, N. C. Well with usual wooden top; water about 25 feet below surface of ground and only a few feet deep; pH 6.4. Several copepods closely resembling the very rare *Cyclops jeanneli* Chappuis were collected as were a few examples of the common (*agilis*) form of *Cyclops serrulatus* Fischer, with furca of moderate length.

#### DISTRIBUTION OF WELL-INHABITING COPEPODS

Only 3 (possibly 2) of 9 wells explored failed to yield cyclopoid copepods before chlorination. The wells may have been deficient in oxygen, but evidence points to a lack of introduction as the cause of the apparent absence of copepods. Copepods (*C. b. navus*) remained alive for weeks in laboratory finger bowls filled with water from wells Nos. 2 and 7, from which no copepods were obtained.

Adjacent wells do not necessarily contain the same species of copepods. Stations Nos. 4 and 5 are very close together, but their copepod fauna is different. More extensive well collections will have to be made before it can be determined if there are underground means by which copepods may be carried from well to well in this area. A small underground stream, but not likely a seepage through sand, would be able to transport cyclopoid copepods from well to well. Heavy rains might convey copepods from surface waters into wells located in low ground. Dirty water buckets, collecting nets, and water samplers might also inoculate wells with copepods, bacteria, and other organisms. On the other hand, most of the species collected in these wells are rare in America and, indeed, are very rarely found in surface streams, lakes, or ponds. Extensive

collections in the latter habitats in the vicinity of Chapel Hill has failed to yield *Cyclops nearcticus*, *Cyclops jeanneli*, or copepods closely resembling them. Kiefer (1934) described *C. nearcticus* from a single female sent by E. G. Hutchinson in 1931 from "Guilder Pond, Berkshires", Massachusetts, and Chappuis (1929) described *C. jeanneli* from examples taken from Morengo Cave in Indiana. These two species have not been reported since their original descriptions. Our records of *C. bicuspidatus navus* at stations Nos. 4 and 6 are the first records, to our knowledge, for this form in the southern part of the United States. It has been collected, however, in Minnesota, Illinois, Wisconsin, and possibly other northern states. *C. crassicaudis brachycercus* has been found only in a collection from New York (Kiefer, 1927), a few collections in Canada (Willey, 1929), and in collections from a particular, isolated rut in Fire Lane Road, Chapel Hill, N. C. Only *C. varicans rubellus* and *C. serrulatus*, which were found at stations Nos. 4 and 9, respectively, are commonly found in the numerous waters about Chapel Hill or have a known wide distribution in America.

#### DESCRIPTIONS OF THE RARER COPEPODS COLLECTED

##### *Cyclops nearcticus* Kiefer

Six examples in our collection were studied. Length of adult females varies from 0.50 to about 0.70 mm., the copepods being distinctly smaller than Kiefer's lone example of *C. nearcticus* which measured 0.80 mm. As with Kiefer's example, our copepods (fig. 1) resemble *Cyclops languidus* Sars. Furcal rami are about 4 times as long as broad (FW/FL, 0.250 to 0.297) and thus have the same proportions as *C. nearcticus* (cf. figs. 2 and 7). The outer lateral seta is attached at a point 69 to 74% of the distance from base to apex of the furcal ramus. Relative lengths of the terminal furcal setae, innermost to outermost, give ratios such as 1.04:11.0:5.40:1 and 1.40:10.40:5.50:1. The innermost terminal seta is thus slightly or substantially longer than the outermost terminal seta, although it is shorter than the furcal ramus (see fig. 2). Kiefer (1934) says this innermost seta is shorter than the outermost in *C. nearcticus* and shows this in his drawing (our fig. 7). Here, then, is a slight distinction between our copepods and the type of *C. nearcticus*.

First antennae are of 17 segments and extend to the posterior margin of the first body segment. The aesthete, or sensory club at the distal end of the 12th antennal segment, extends about to the middle of the 15th segment.

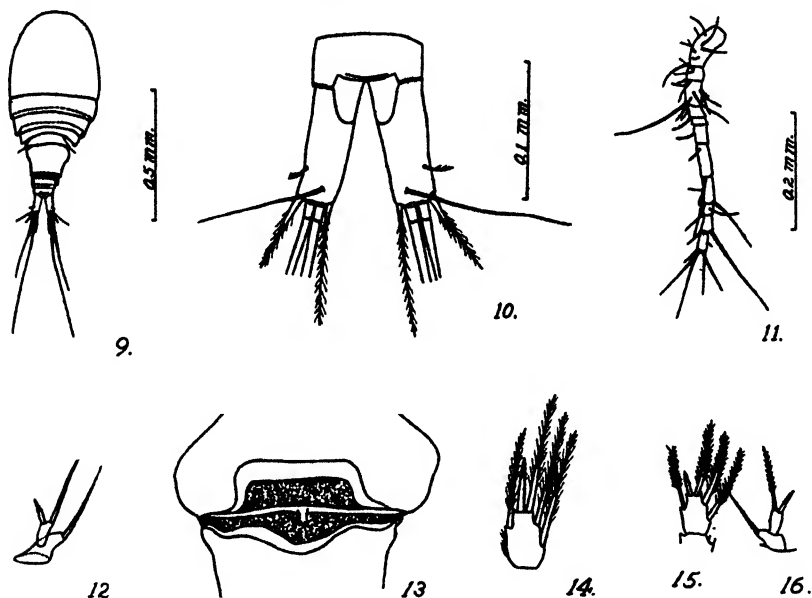
Swimming feet have the inner and outer rami of 3 segments. Spine formula of the terminal segments of the exopods is 2, 3, 3, 3. The complete armature of these feet is like that of *Cyclops bicuspidatus* Claus, except there is only one instead of two setae on the inner side of the second segment of the endopod of all four pairs of feet and a spine instead of a seta on the outer side of the terminal segment of the endopod of the fourth foot. Figure 8 is a copy of Kiefer's drawing of part of the fourth foot of *C. nearcticus*; it shows only one seta on the second segment of the endopod, as in our copepods (fig. 3).

The terminal segment of the endopod of the fourth foot is about 1.24 to 1.40 times as long as wide, thus being slightly stubbier than that of *C. nearcticus* (1.52 times as long as wide). The inner terminal spine is 1.14 to 1.23 times

longer than the segment and 1.14 to 1.16 times (about 1.42 times in *C. nearcticus*) longer than the outer terminal spine. As in *C. nearcticus* a short firm spine instead of a seta is on the outer side of this segment (figs. 3, 4 and 8).

The fifth foot (fig. 5) is much like that of *C. bicuspidatus* and other members of that subgroup. The seminal receptacle of an anesthetized female is shown in fig. 6.

Our examples are almost identical with *Cyclops nearcticus* as scantily described by Kiefer (1934) from a single specimen. The only real difference, innermost terminal furcal seta slightly longer instead of shorter than the outermost ter-



FIGS. 9-16: *Cyclops jeanneli* Chappuis and *Cyclops jeanneli putei*, n. subsp.

Fig. 9. Adult female *C. j. putei* from Orange County, N. C.

Fig. 10. Dorsal view of furcal rami and last abdominal segment of *C. j. putei*.

Fig. 11. First antenna of *C. j. putei*.

Fig. 12. Fifth foot of *C. j. putei*.

Fig. 13. Seminal receptacle of an anesthetized female of *C. j. putei*.

Fig. 14. Terminal segment of endopod of 4th foot of *C. j. putei*.

(Figs. 10 and 12-14 drawn to same scale.)

Fig. 15. Terminal segment of endopod of 4th foot of *C. jeanneli* (after Chappuis, 1929).

Fig. 16. Fifth foot of *C. jeanneli* (after Chappuis, 1929).

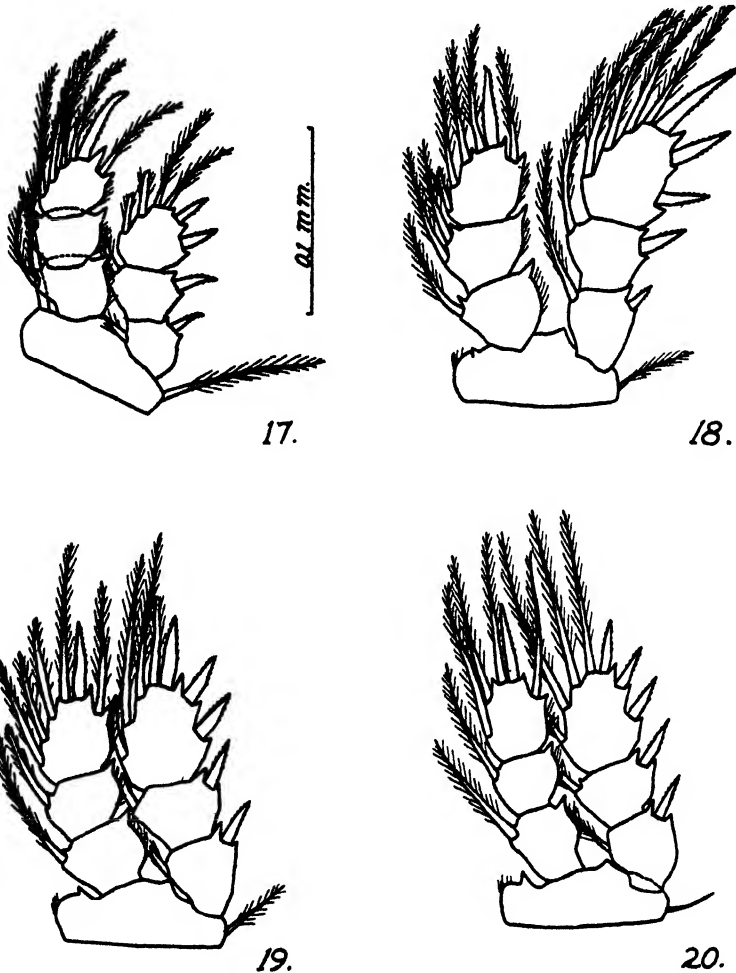
minal seta, is so slight that we identify our copepod as only a variant of *Cyclops nearcticus* Kiefer. The armature of the swimming feet, especially that of the fourth, separate this species from others with which it might be confused because of a similarity in the fifth foot.

Taken at station No. 3. Reported also from a single locality in Mass.

*Cyclops jeanneli putei*, n. subsp.

Three adult females and several males were examined but only the females are described here. Length of body of the females is 0.76 to 0.85 mm., not

including the terminal furcal setae, and thus our copepods are slightly smaller than Chappuis' *C. jeanneli*, which are about 0.9 mm. As in *C. jeanneli*, the genital segment is very broad (see fig. 9) and the anal operculum extends rather far posteriorly.



FIGS. 17-20: *Cyclops jeanneli putei*, n. subsp.  
(All figures drawn to the same scale.)

Fig. 17. First foot. Note single seta on second segment of endopod.

Fig. 18. Second foot. Note two setae on second segment of endopod.

Fig. 19. Third foot. Note single seta on second segment of endopod.

Fig. 20. Fourth foot. Note single seta on second segment of endopod and replacement of long inner spine at terminal end of endopod by a long seta.

Furcal rami are about 3 times as long as broad (3.5 times as long as broad in *C. jeanneli*). Lateral seta is attached at a point 69 to 71% of the distance from base to apex of ramus. Relative lengths of the terminal furcal setae, innermost to outermost, give ratios such as 1.55:10.22:6.44:1 and 1.6:11.25:6.50:1 (about

2:12.5:7.5:1 in *C. jeanneli*). Here is a slight difference between our copepods and *C. jeanneli*, which has a relatively shorter outer terminal seta. The innermost terminal seta may be about the same length or slightly longer than the furcal ramus (fig. 10).

First antennae (fig. 11) are of 11 segments and extend to or slightly beyond the posterior border of the first body segment. First antennae of *C. jeanneli* are of 17 segments (Chappuis, 1929); there is a clear distinction between these two forms. The aesthete of the 7th segment extends slightly beyond the distal end of the 8th segment (fig. 11).

Inner and outer rami of the swimming feet are of three segments. Spine formula of the terminal segments of the exopods is 2, 3, 3, 3. Figures 17-20 show the four pair of swimming feet and their unusual armature. Note that there is only one seta on the inner side of the second segment of the endopod of the 1st, 3rd, and 4th feet, as in our *C. nearcticus* examples, but that the 2nd foot has two setae at this place. Chappuis (1929) did not give the armature of the feet of *C. jeanneli*, so that we cannot compare these parts.

Terminal segment of the endopod of the 4th foot is about 1.4 to 1.66 times (1.5 times in *C. jeanneli*) longer than broad. There is a long seta instead of a long, inner terminal spine in our examples as well as in *C. jeanneli* (see figs. 14, 20, and 15). No other copepods, to our knowledge, have a seta here instead of a spine. This seta is 1.95 to 2.25 times longer than the segment and 1.91 to 2.25 times longer than the outer terminal spine. By our measurement of Chappuis' drawing (our fig. 15), this long seta is 2.07 times as long as the segment and 2.9 times longer than the outer spine. The fifth foot (fig. 12) is like that of *C. jeanneli* (fig. 16). The seminal receptacle (fig. 13) is very much like that of *C. crassicaudis*. There is a short tube extending from the outside opening to the chamber of the receptacle.

Since our copepods resemble *C. jeanneli* so closely in all respects except in the number of segments of the first antennae, and we are sure our examples are sexually mature, we can only consider them as representing a subspecies of *C. jeanneli*. A similar case is that of *C. b. lubbocki* which has first antennae with 14 segments and is generally considered a subspecies of *Cyclops bicuspidatus* with 17-segmented antenna. For our examples, we propose the subspecific name *putei*, referring to its discovery in a well. More than any other species that we have examined in the living state, *C. jeanneli putei* has the ability to adhere to the glass in a pipette when the water is forcibly expelled.

In general appearance *C. jeanneli* and *C. j. putei* closely resemble *C. crassicaudis* Sars; they differ from that species in having a long seta instead of a long spine at the inner distal end of the endopod of the 4th foot, 11 or 17 instead of 12 segments in the first antenna, and the innermost terminal furcal seta longer than the outermost instead of shorter.

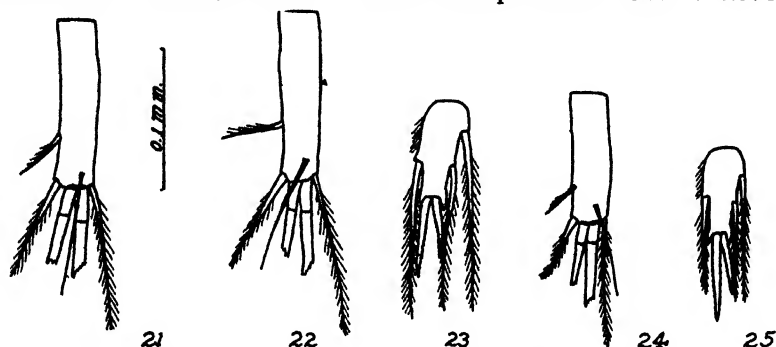
The species is known only from a cave in Indiana; the subspecies only from a well (No. 9) in Orange county, N. C.

#### *Cyclops bicuspidatus navus* Herrick

Since we have described examples of the *C. b. navus* collected at Wilkie farm (station No. 4) in a previous paper (Yeatman, 1943), we merely compare them now with the examples collected at station No. 6 near Moncure, N. C.

Adult female copepods from Moncure measured 0.90 to 1.00 mm. in length, not including the furcal setae, whereas the copepods from Wilkie farm averaged slightly larger but varied from 0.9 to 1.15 mm. As is readily apparent from the figures, the furcal rami of the former were much slimmer (FW/FL = 0.213 to 0.225 or between 4 and 5 times as long as broad—figs. 21, 24). In spite of this slenderness of the furcal rami of the Moncure examples, the small lateral seta averages no closer to the middle of the ramus than in the stubbier Wilkie examples. *Cyclops bicuspidatus* Claus, of which we still questionably consider *C. b. navus* a subspecies, has a very slender furcal ramus and the outer lateral seta at a point about the middle of the ramus. Attempts to mate the variants of *C. b. navus* with *C. bicuspidatus* and *C. bicuspidatus thomasi* S. A. Forbes will have to be made before we can know the specific status of these forms.

Quotient of length into width of the terminal segment of the endopod of the 4th foot is 0.340 to 0.370 in the Moncure examples and 0.330 to 0.375 in the



FIGS. 21-25: *Cyclops bicuspidatus navus* Herriek  
(All figures drawn to the same scale.)

Figs. 21 & 22. Furcal rami; example from well near Moncure.

Fig. 23. Terminal segment of endopod of 4th foot; example from well near Moncure, N. C.

Note that setae extend beyond distal end of the longer terminal spine

Fig. 24. Furcal ramus; example from well on Wilkie Farm.

Fig. 25. Terminal segment of endopod of 4th foot; example from well on Wilkie Farm.

Note that setae do not extend beyond distal end of the longer terminal spine.

Wilkie examples. Quotient of length of the segment into length of the inner of the two terminal spines is 0.831 to 0.850 in the Moncure examples and 0.937 to 1.01 in the Wilkie examples. Thus the inner spine in the Wilkie copepods is longer relative to length of the segment than it is in the Moncure examples. The setae of this segment extend far beyond the ends of the terminal spines in the Moncure examples (fig. 23), but such is not true in the Wilkie examples (fig. 25). The copepods from both collections were alike in all respects, other than those mentioned above. Thus the Moncure examples differ from the Wilkie examples in proportion of the furcal rami and in relative lengths of the setae and spines of the terminal segment of the endopod of the 4th swimming foot. Such differences seem to be genetic rather than environmental since they have remained constant in our cultures of the two lines. We have not attempted to mate copepods from the two lines, nor have we reared them under known experimental conditions.

Found at stations 4 and 6. The subspecies was known before only from North Central States.

All our *C. b. navus* were very white when taken from the wells, but when placed in fingerbowls with good light and an abundance of food (*Euglena*, *Paramoecium*, etc.), they become reddish brown in color because of the presence of oil droplets which seem to be stored food.

*Cyclops varicans rubellus* Lilljeborg taken at the Wilkie farm well is a fairly common species in surface waters: it is discussed in another paper (see Yeatman, 1943). *Cyclops crassicaudis brachycercus* Kiefer is treated in the same paper.

*Cyclops serrulatus* Fischer, taken at station No. 9, has extremely wide distribution.

#### SUMMARY

In Orange and Chatham counties, N. C., nine wells were explored with the plankton net hauled vertically, or in one case by drawing a bucket of water in the usual way.

Six yielded cyclopoid copepods and sometimes in considerable numbers.

Of 5 species taken: one is of almost universal distribution—*C. serrulatus* Fischer; another is a not uncommon species in surface waters of the region—*C. varicans rubellus* Lilljeborg; a third is a very rare species in America and, in this geographic region, has been known only from one temporary spring-fed pool—*C. crassicaudis*; two have never before been found in the region in spite of intensive searches of surface waters about Chapel Hill—*C. bicuspidatus navus*, known previously from North Central States and *C. nearcticus* Kiefer, hitherto known only from a single example taken in a pond in Massachusetts; the sixth is a new subspecies (if not a good species), clearly related to, but distinct from a copepod described by Chappuis from a cave in Indiana—*C. jeanneli putei*, n. subsp.

Only two species, *C. crassicaudis brachycercus* and *C. bicuspidatus navus*, were taken in more than one well and in each case the two wells investigated were many miles apart.

The results suggest that there may be a distinctive fauna of wells but throw no light on the origin of the fauna. The need for more general explorations of wells and subterranean waters is definitely indicated.

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# NEW SPECIES OF NOWAKOWSKIELLA AND BLASTOCLADIA<sup>1</sup>

BY ALMA J. WHIFFEN

## PLATES 2-4

From one soil collection made at Terrell, Texas, two different fungi were obtained on grass leaf bait. One fungus proved to be a new species of *Nowakowskiella*, a genus of the Chytridiales, and the other a new species of *Blastocladia*, a genus of the Blastocladales. The species of *Nowakowskiella* was isolated in unifungal culture by allowing several zoosporangia to discharge their spores in a drop of water, the zoospores then being transferred in a capillary pipette to a Petri dish containing a piece of boiled grass leaf and sterile water. A unifungal culture of the species of *Blastocladia* was established by dissecting from the grass leaf bait a number of mature resting bodies, which were dried and later induced to germinate by the addition of water. Since very few zoosporangia were produced by the *Blastocladia* and only a small number of new plants appeared in the cultures, material for study was obtained when needed by the germination of dried resting bodies.

At the present time four species of *Nowakowskiella* are recognized. Two of these species, *N. hemisphaerospora* (Shanor, 1942) and *N. profusum* (Karling, 1941), were described in the past two years. The other two species are *N. ramosa* (Butler, 1907) and *N. elegans* (Schroeter, 1897). Of these four species the present new species is most similar to *N. elegans* but differs from *N. elegans* in its more slender and less extensive rhizomycelium, in its more spherical apophysis, smaller zoosporangia, and smaller oil globules in the spores, and in its production of resting bodies. Because of the delicate character of the rhizomycelium, this new species of *Nowakowskiella* is named *N. delica*.

### *Nowakowskiella delica* n. sp.

Rhizomycelium, intra- and extramatrical, much branched with numerous elongated swellings, which give rise to zoosporangia or resting bodies. Zoosporangia, terminal or intercalary,  $12.5 \times 15.0 \mu$  to  $22.5 \times 28.8 \mu$ , spherical, ovoid, or pyriform; with a single exit pore, usually laterally but often apically placed, operculate; apophysis variable in shape,  $2.5 \times 15.0 \mu$  to  $11.5 \times 17.5 \mu$ . Zoospores hyaline, spherical,  $5.7-7.5 \mu$ , posteriorly uniflagellate, flagellum  $30 \mu$  long, uniguttulate. Resting bodies, terminal or intercalary, usually intramatrical, ovoid to spherical,  $10.0 \times 15.0 \mu$  to  $26.2 \times 29.9 \mu$ , apophysate, hyaline, containing one to many oil globules. Germination of resting bodies not observed.

Saprophytic on a grass leaf placed in a soil collection made December 28, 1941, by Dr. J. N. Couch and Philip Couch at Terrell, Texas.

<sup>1</sup> This work was supported by a grant from the Penrose Fund of the American Philosophical Society. I wish to express my grateful appreciation to Dr. J. N. Couch for his interest in this study.

Extensive growth and branching of the rhizomycelium for a period of two or three days after inoculation of the grass leaf precedes the formation of the spindle-shaped swellings, which later may develop into zoosporangia or resting bodies. Frequently resting bodies are formed on the intramatrical portion of the rhizomycelium before any zoosporangia begin development. Maturation of the zoosporangia on the rhizomycelium is not simultaneous, for all stages of zoosporangial development may be seen along a line drawn from the point of inoculation to the tip of the youngest branch of the rhizomycelium (Fig. 11). As the zoosporangia mature and discharge their spores, the proximal portion of the rhizomycelium becomes vacuolate and inactive.

The origin of the apophysis is of interest in this species. After the enlargement of a terminal zoosporangial swelling is completed, a cross wall forms a little above the base of the swelling, so that the zoosporangium proper is subtended by an apophysis. In a non-apophysate species such as *N. hemisphaerospora* the cross wall, delimiting the zoosporangium from the rest of the rhizomycelium, develops at the base of the zoosporangial swelling. In *N. delica* because of the formation of the apophysis, only a portion of the protoplasm within the swelling is utilized in the development of the zoosporangium for the protoplasmic material thus cut off in the apophysis usually disintegrates. It should be noted that the apophysis is always cut off at the end of the swelling which is continuous with the older and dying portions of the rhizomycelium. Sometimes, however, the contents of the apophysis do not disintegrate as the zoosporangium matures (Fig. 9), whereupon the apophysis itself may enlarge, later being divided by a cross wall into zoosporangial and apophysate portions. In *N. delica* the usual condition in which the apophysis is cut off from the zoosporangium after the zoosporangial swelling has reached its maximal size is in contrast with the development described by Berdan (1941) for the apophysate species, *Cladochytrium hyalinum*. Here the zoosporangium and apophysis continue to increase in size after the formation of the wall delimiting the apophysis from the zoosporangium.

*Nowakowskiella delica* offers favorable material for following the stages in the development of the zoospores within the zoosporangium, because after the cutting off of the apophysis, the formation of the zoospores proceeds rapidly and is complete within ten or twelve hours. At about the time that the exit papilla makes its appearance, the refractive material in the zoosporangium is dispersed in small globules throughout the peripheral protoplasm which encloses a central vacuole. Upon the gradual disappearance of the central vacuole, the protoplasm throughout the zoosporangium appears to be cut up into numerous small masses, corresponding to the size of the zoospores (Fig. 3). Slowly the dispersed oil globules within each mass aggregate to form the single oil globule characteristic of the zoospores (Fig. 4, 5). Finally, preceding spore discharge, the protoplasm assumes an appearance of clearness in which it is impossible to determine with certainty the outlines of the individual zoospores (Fig. 6).

Resting bodies, like the zoosporangia, are apophysate (Fig. 13). The swelling which will give rise to a resting body cannot be differentiated from that which

will develop into a zoosporangium until after the formation of the apophysis. Then an incipient resting body can be recognized by the accumulation of numerous oil globules. As the resting body matures, these oil globules coalesce until as few as one, two, or three large oil globules remain. The wall of the resting body is only slightly thicker than that of the zoosporangium.

For *Cladochytrium elegans*, Schroeter (1897) created a new genus, *Nowakowskiella*, which was separated from *Cladochytrium* by the presence of an operculum in *Nowakowskiella* and the absence of an operculum in *Cladochytrium*. By use of the operculate or inoperculate character species are brought together in the same genus which are similar only in having or lacking the operculum and species, which are similar in every way except for the presence or absence of the operculum, are thus separated in two different genera. *Cladochytrium crassum* Hillegas (1941) resembles *Nowakowskiella profusum* Karling (1941) in the coarseness of the rhizomycelium, the lack of septations in the spindle-shaped swellings, the non-apophysate character of the zoosporangia, and the form of the resting bodies. *Cladochytrium hyalinum* Berdan (1941) is like *Nowakowskiella ramosa* Butler (1907) in the non-septate spindle-shaped swellings, the apophysate zoosporangia, and the formation of "pseudo-parenchyma" at the base of the resting body.

There is one character of the rhizomycelium in which all species of *Nowakowskiella*, as the genus is now constituted, agree and this character is the lack of septations in the spindle-shaped swellings of the rhizomycelium. Karling (1931) suggests that it is a matter of definition as to whether or not these spindle-shaped swellings in *Nowakowskiella* may be considered as true spindle organs. The spindle organs of *Cladochytrium replicatum*, which may be regarded as being typical, are cut off from the rest of the rhizomycelium by cross walls and seldom are directly transformed into zoosporangia or resting bodies. The swellings in the rhizomycelium of *Nowakowskiella* are continuous with the rest of the rhizomycelium and usually enlarge into zoosporangia or resting bodies. Neither *Cladochytrium hyalinum* nor *C. crassum* has typical septate spindle organs, a fact pointed out by Hillegas (1941) in comparing his species, *C. crassum*, with *C. tenue*. It is interesting that the two species in *Cladochytrium*, which differ from the other species in the genus in the lack of septations in the spindle-shaped swellings, are the two species that correspond so closely to the two species of *Nowakowskiella*, *N. profusum* and *N. ramosa*, as indicated above. The decision as to whether or not the septate or non-septate character of the spindle-shaped enlargements of the rhizomycelium is of more fundamental significance than the absence or presence of an operculum as a basis for separation of *Cladochytrium* and *Nowakowskiella*, must await further study of the species in the two genera and the discovery of new forms relating to these genera. Some students of the Chytridiales might prefer to remove from *Cladochytrium* the species which lack the septate spindle organs and to erect for them a new genus separated from *Nowakowskiella* by the absence of an operculum.

In Table 1 five species of *Nowakowskiella* and four of the better known species of *Cladochytrium* are compared as to the distribution among them of four characters: (1) nature of the spindle-shaped swellings, (2) the origin and form of the

resting bodies where known, (3) presence or absence of an operculum, (4) and presence or absence of an apophysis. Apophysate and non-apophysate species are found in both genera. Likewise there is variation in both genera as to the origin and form of the resting body.

The species of *Blastocladia* from Texas soil is remarkable for its smallness of size and simplicity of structure. The plant body, consisting of a cylindrical basal body and dichotomous branches, which lack pseudosepta and terminate in resting bodies or zoosporangia, is typically that of *Blastocladia*. In the smooth wall of the resting body and the presence of more than one exit papilla on the zoosporangium this species differs from all other described species of *Blastocladia*. Because of its small size, this species is given the name of *Blastocladia parva*.

TABLE 1  
*Comparison of species of Nowakowskiella and Cladochytrium*

SPECIES	SPINDLE ORGANS	R.B.	OPERCULUM	APOPHYSIS
<i>N. elegans</i> .....	non-septate	unknown	present	present
<i>N. ramosa</i> .....	non-septate	with pseudo-parenchyma	present	present
<i>N. profusum</i> .....	non-septate	typical	present	absent
<i>N. hemisphaerospora</i> .....	non-septate	two-celled	present	absent
<i>N. delica</i> .....	non-septate	typical	present	present
<i>C. replicatum</i> .....	septate	typical	absent	absent
<i>C. tenue</i> .....	septate	unknown	absent	absent
<i>C. hyalinum</i> .....	non-septate	with pseudo-parenchyma	absent	present
<i>C. crassum</i> .....	non-septate	typical	absent	absent

### *Blastocladia parva* n. sp.

Plant body cylindric, slender, 32 to 170  $\mu$  high, 12.5 to 50.0  $\mu$  wide; branching sub-dichotomous to dichotomous. Zoosporangia, irregular in shape, 40.0 x 65.6  $\mu$  to 41.3 x 90.2  $\mu$ , with one to six exit papillae. Zoospores from germinated resting bodies, posteriorly uniflagellate, with several small oil globules and a conspicuous food body, 5.6–6.1  $\mu$  x 2.8–3.2  $\mu$ . Resting bodies spherical, elliptic, ovoid, 36.8 x 41.0  $\mu$  to 35.2 x 77.1  $\mu$ ; wall smooth, pale yellow in color; germination by cracking of outer wall and discharge of zoospores through one or two exit papillae.

Saprophytic in soil from Terrell, Texas, collected December 28, 1941, by Dr. J. N. Couch and Philip Couch.

Germination\* of resting bodies one month old or older, is readily induced, after a few days of drying, by the addition of water. The process of germination is the same as that described for *Blastocladia Pringsheimii* by Blackwell (1940) and for *Blastocladia simplex* by Matthews (1937). No evidence of fusion of the zoospores from the resting bodies could be found. Zoospores from a large number of resting bodies were allowed to swim for an hour or longer before being killed with osmic acid and stained with gentian violet. All zoospores were then found to be uniflagellate.

Zoospores from germinated resting bodies develop into plants that are like those which previously bore the resting bodies. Development of the plant body is

rapid at room temperature, its growth and maturation being accomplished within four or five days. Branching of the germ tube gives rise to the intramatrical rhizoidal system while the elongating body of the spore constitutes the beginning of the basal body (Fig. 18, 19), which apically branches dichotomously or subdichotomously three to five times (Fig. 20). Upon the completion of the last dichotomy, elongation of the plant body ceases and protoplasm accumulates in the rapidly swelling tips of the branches. This enlarged apical portion of the branch is cut off by a cross wall and may develop into either a zoosporangium or a resting body (Fig. 21).

The development of the resting body is completed in about twenty-four hours (Fig. 25-28). As the wall of the resting body thickens, the oil globules break up into equal-sized particles and become evenly dispersed throughout the protoplasm. The thick outer wall of the resting body may be either widely separated or inseparable from the wall of the branch enclosing it.

During the course of this study zoosporangia were found but rarely. They developed on the same plant as the resting bodies (Fig. 33). Whether zoosporangia or resting bodies are produced in the greater abundance may be determined by conditions of the environment but the exact conditions which are necessary for the development of the zoosporangia are not known. At 24° and 25° C. only resting bodies were produced but in three cultures grown at 21°C. about a dozen zoosporangia were found.

Though more complex in form than any species of *Blastocladiella*, *Blastocladia parva* indicates a possible transition from the small tubular, unbranched body of *Blastocladiella simplex* to the large much branched plant body of such a species of *Blastocladia* as *B. ramosa*. In a culture of *Blastocladia parva* there are to be found plants with a single dichotomy, producing only two reproductive structures, plants with two dichotomies and four resting bodies, and finally plants with three to five successive dichotomies and eight to thirty-two resting bodies. The number of resting bodies, however, is variable and does not have a constant ratio with the number of dichotomies since not every branch tip matures into a resting body. Dichotomy in this case may be recognized as a more primitive type of branching than the sympodial, racemose, or cymose arrangements of branches, which are characteristic of the arbusculoid species of *Blastocladia*.

#### SUMMARY

Two new species are described. *Nowakowskiella delicata* n. sp. is characterized by a delicate rhizomycelium with apophysate zoosporangia and resting bodies. Five species of *Nowakowskiella* and four species of *Cladochytrium* are discussed and compared on the basis of characteristics of the rhizomycelium.

*Blastocladia delicata* n. sp. differs from all other described species of *Blastocladia* in the smooth wall of the resting body and the presence of more than one exit papilla on the zoosporangium. The possible derivation of this species from such a form as *Blastocladiella simplex* is discussed.

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## EXPLANATION OF PLATES

## PLATE 2

*Nowakowskiella delicata*

- Fig. 1. Zoospores.  $\times 850$ .
- Fig. 2. Spore discharge.  $\times 850$ .
- Figs. 3-6. Stages in development of a zoosporangium.  $\times 850$ . Fig. 3—2:40 P.M. Fig. 4—2:50 P.M. Fig. 5—4:30 P.M. Fig. 6—9:00 P.M.
- Fig. 7. Zoosporangial swelling.  $\times 850$ .
- Fig. 8. Zoosporangial swelling after the cutting off of the apophysis.  $\times 850$ .
- Fig. 9. An empty zoosporangium, subtended by an apophysis which is an incipient zoosporangium.  $\times 850$ .
- Fig. 10. Habit sketch of *N. elegans*.  $\times 110$ .
- Fig. 11. Habit sketch of *N. delicata*.  $\times 110$ .
- Fig. 12. Intramatrical rhizomycelium.  $\times 600$ .
- Fig. 13. Resting bodies.  $\times 850$ .

## PLATE 3

## Photomicrographs

- Fig. 14. Rhizomycelium of *Cladochytrium replicatum* on agar.  $\times 400$ . Note septate spindle organs. Photomicrograph by J. N. Couch.
- Fig. 15. Rhizomycelium of *Nowakowskiella hemisphaerospora* on agar.  $\times 150$ . Note non-apophysate zoosporangia and lack of septate spindle organs.
- Fig. 16. Rhizomycelium of *Nowakowskiella elegans* on agar.  $\times 430$ . Compare with the rhizomycelium of *C. replicatum*.

## PLATE 4

*Blastocladia parva*

- Fig. 17. Zoospore from resting sporangium.  $\times 850$ .
- Fig. 18. Germling, 12 hours old, from agar culture.  $\times 300$ .
- Fig. 19. Young thallus. 3:30 P.M.  $\times 300$ .
- Fig. 20. Thallus showing dichotomous mode of branching. 10:00 P.M.  $\times 300$ .

Fig. 21. Thallus on which resting bodies are being cut off. 10:00 A.M.  $\times 200$ .

Fig. 22. Thallus with matured resting bodies. 8:00 P.M.  $\times 200$ .

Fig. 23. A much reduced thallus from an agar culture 24 hours old.  $\times 300$ .

Fig. 24. A reduced thallus from a leaf culture, three days old.  $\times 110$ .

Figs. 25-28. Stages in the development of two resting bodies.  $\times 300$ . Fig. 25—10:15 A.M.

Fig. 26—2:00 P.M. Fig. 27—7:30 P.M. Fig. 28—10:30 A.M.

Fig. 29. A resting body which appears to have developed from an incipient zoosporangium.  
                     $\times 530$ .

Fig. 30. A mature resting body.  $\times 600$ .

Figs. 31-32. Two stages in the germination of a resting body.  $\times 600$ .

Fig. 33. A thallus which produced both resting bodies and zoosporangia.  $\times 110$ .

Fig. 34. Zoosporangium.  $\times 300$ .

Fig. 35-36. Two empty zoosporangia.  $\times 300$ .





PLATE 2

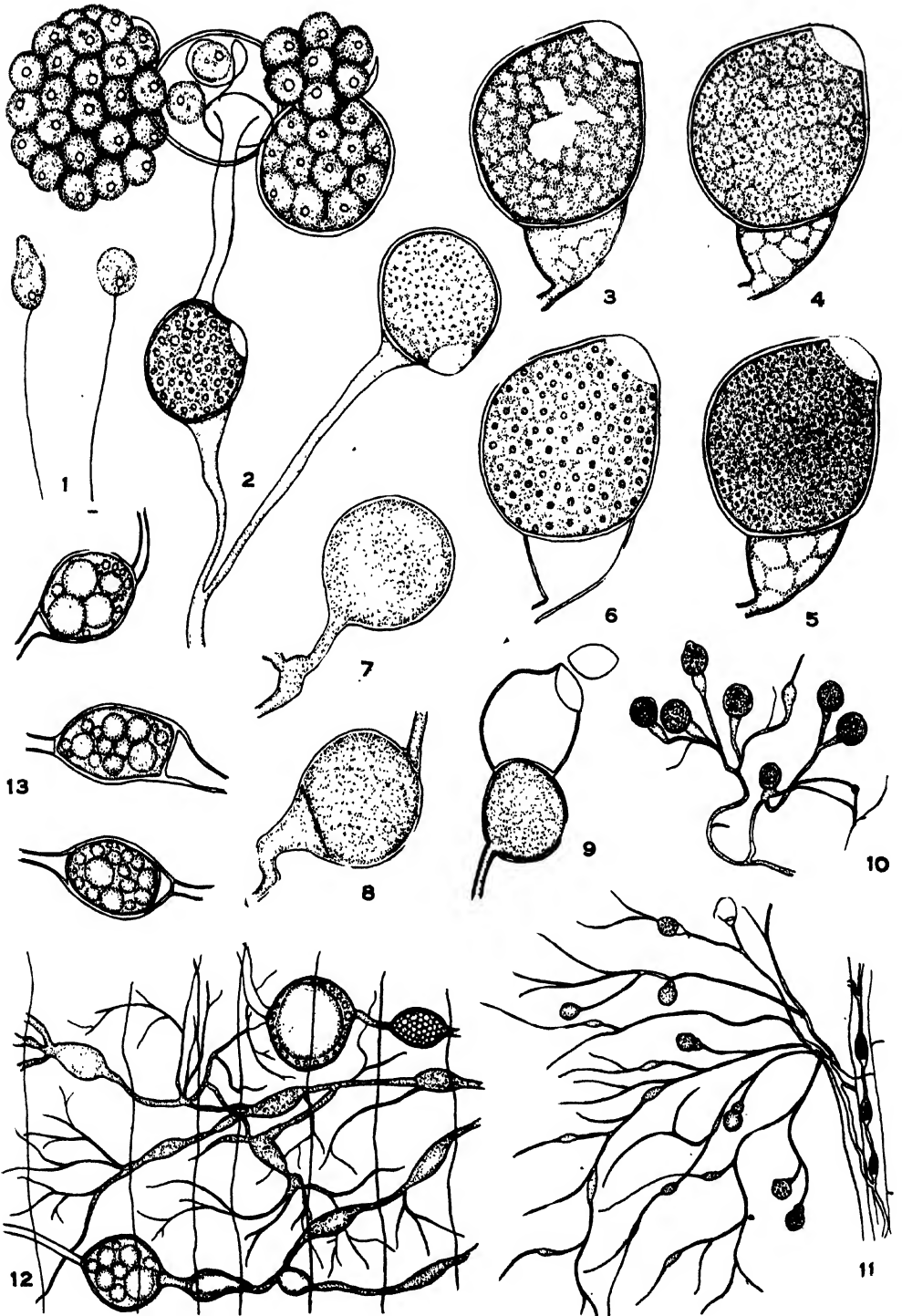


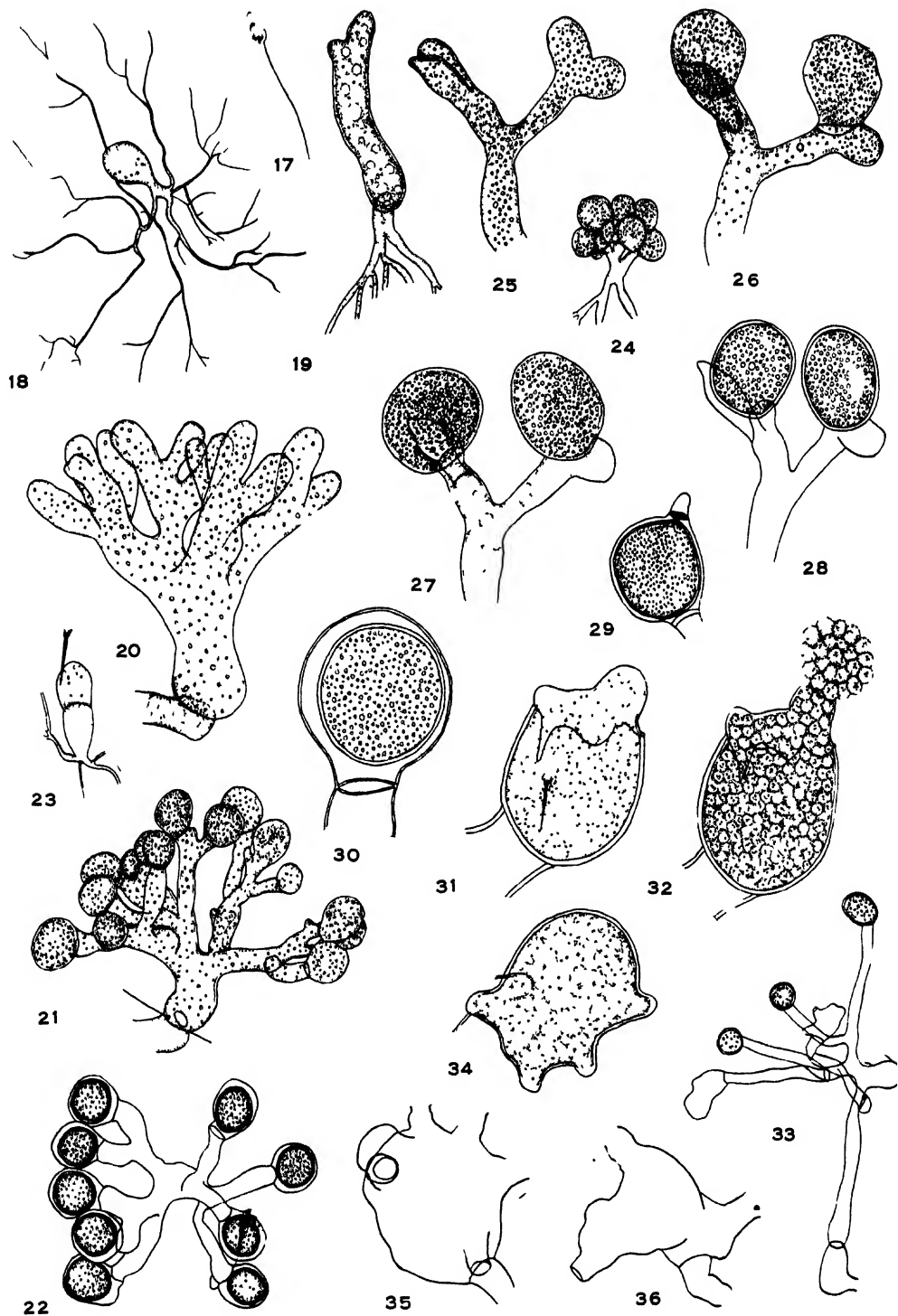


PLATE 3





# PLATE 4





# MORPHOLOGY, CYTOLOGY, AND PARASITISM OF THEKOPSORA HYDRANGEAE

BY LINDSAY S. OLIVE

## PLATES 5-12

### INTRODUCTION

*Thekopsora hydrangeae* Magn. is a heteroecious rust occurring abundantly in the mountains of our state on *Tsuga canadensis* and on several species of *Hydrangea*. Adams (1) proved by successfully inoculating leaves of *Hydrangea arborescens* with aeciospores from a rust resembling *Thekopsora vacciniorum* Karst. on *Tsuga canadensis* that the Canadian hemlock is the alternate host of *Thekopsora hydrangeae*.

The rust was pointed out to the writer by Professor W. C. Coker during a summer session at the Weyman Memorial Laboratory in Highlands, North Carolina. We have since found the rust in the vicinity of Asheville and Brevard in this state. Arthur (3) reports its pycnial and aecial phases on *Tsuga canadensis* (L.) Carr. in Indiana, Pennsylvania, Tennessee, and West Virginia, and on *T. caroliniana* Engelm. in North Carolina. The only alternate host for the uredinial and telial phases, as listed by Arthur, is *Hydrangea arborescens* L. We have found pycnia and aecia in abundance on *Tsuga canadensis* in this state, but no indications of it on *T. caroliniana*, although a considerable number of the latter species were examined carefully for the disease. In addition to finding uredinial and telial phases on *Hydrangea arborescens*, we have also found these stages abundantly on two other species of *Hydrangea*, *H. radiata* Walt. and *H. cinerea* Small.

Two other rusts, in addition to *Thekopsora hydrangeae*, were found on hemlocks in our area. *Thekopsora vacciniorum* was found sparingly on *Tsuga canadensis*, while its alternate hosts were *Azalea viscosa* L. var. *montana* Rehd., *A. arborescens* Pursh., *A. calendulacea* Michx., and *Cyanococcus similatus* Small. The latter three species have apparently not been reported among the hosts of this rust. One other rust occurring frequently on twigs and leaves of the Canadian hemlock is *Melampsora abieti-canadensis* (Farl.) C. A. Ludwig. The infections were found, upon microscopic examination, to contain numerous aecia. This rust causes the twigs to become yellowish and contorted.

It is expedient at this point to explain the nomenclature used in this paper. Adams (2) included all species belonging to the families *Coleosporiaceae*, *Melampsoraceae*, and *Uredinaceae*, with pycnia and aecia on gymnosperms, in one genus, *Peridermium*. The rusts included in this system are so varied that the present writer prefers to retain their former family and generic identities. Arthur (3) places in the genus *Pucciniastrum* forms with pycnia and aecia on various coniferous genera of the *Abietaceae*, and with uredinia and indehiscent telia with vertically septate teliospores on seed plants. Magnus, in 1878, included the species in this latter group under two genera, *Phragmopsora* and *Thekopsora*,



respective of whether the teliospores are sub-epidermal or intra-epidermal. Pady (13), in a recent paper on teliospore development in this group, employs the generic name, *Thekopsora*, for species with intra-epidermal teliospores and retains the name *Pucciniastrum* for the species with sub-epidermal teliospores. The present writer prefers the usage of this last mentioned system of classification.

The chief purposes of this paper are to help clarify the position of this type of rust with relation to other groups and to present certain new findings in this group, or possibly for the rusts as a whole.

#### MATERIALS AND METHODS

Leaves of *Tsuga canadensis*, infected by *Thekopsora hydrangeae*, were collected on the grounds of the Weyman Memorial Laboratory in Highlands, North Carolina, during the month of June, 1941. Pycnia appeared during the earlier part of the month, while aecia were beginning to open by the middle of June. The uredinal stage was collected on the leaves of *Hydrangea arborescens*, *H. radiata*, and *H. cinerea* on the first of September and again in the middle of October. Fallen leaves with mature teliospores were collected from the ground around hydrangea bushes in October and December, 1941, and in March, 1942.

Diseased leaves of both the hemlock and hydrangea were fixed in formalin-acetic-alcohol and Flemming's weaker chromic-acetic-osmic acid solution. Small squares of the leaves were washed and embedded in paraffin. Sections were cut 6-7  $\mu$  thick.

Various staining procedures were carried out on sectioned material. A modification of Gram's Crystal Violet technique was quite useful in bringing out dividing nuclei against a clear cytoplasmic background. Heidenhain's hematoxylin was an indispensable nuclear stain and the most desirable one for bringing out nuclear details at all stages. Safranin and gentian violet were particularly useful in revealing certain important developmental details which were entirely lacking in material stained by the other two methods.

#### MACROSCOPIC OBSERVATIONS

The first external sign of the rust on hemlock leaves is the appearance of numerous little pycnia on the under surface. Frequently pycnia are also found on the upper surface, but never so abundantly as on the lower. They are rather inconspicuous and likely to be overlooked at first. With a hand lens one may observe that a sticky secretion is exuding from the ostiole of each mature pycnium. This sweet, sticky substance, which contains the pycniospores, presumably attracts insects, which spread the pycniospores from one pycnium to another.

Aecia appear at first as yellow dome-shaped protrusions on the lower surface of the leaf. They soon elongate and break open at the apex. The long, delicate peridia are quite conspicuous. The aecia are arranged in an orderly row along each side of the midrib, while pycnia are scattered in irregular fashion over the lower surface of the leaf (figs. 59 and 60). The infection causes the leaves to drop off early.

Uredinia appear later on in the season as small, bright orange-colored spots scattered profusely over the lower surface of hydrangea leaves. Uredospores continue to re-infect the hydrangea until the latter part of October. The telia of this rust are quite inconspicuous. If the upper epidermis of hydrangea leaves infected with old uredinia are examined in October, it may be seen to contain small brown patches or extensive brownish areas, which are groups of epidermal cells containing numerous teliospores. These spores remain viable and overwinter in the fallen leaves. All attempts to make the teliospores germinate precociously were unsuccessful. In the spring, if the leaves are moistened, basidia appear abundantly and impart a whitish bloom to the upper surface of the leaves.

#### MICROSCOPIC OBSERVATIONS

##### *Early Infections on the Hemlock*

The earliest infection stages observed were in sections of infected leaves in which pycnia had not yet appeared. These sections revealed the presence of numerous hyphae running through the leaf for considerable distances, ranging from the base of the leaf almost to the tip in some instances. These hyphae are much-branched and septate, with considerable intervals between septa. The branching hyphae extend from the upper to the lower surface of the leaf and their haustoria penetrate the host cells. These haustoria are most abundant after the aecia have appeared. They will be discussed more in detail later. The haustoria and cells of the intercellular mycelium are uninucleate.

Characteristic of this rust are the numerous hyphae which appear early beneath the cuticle and run for long distances parallel to the long axis of the leaf. These sub-cuticular hyphae are found beneath the cuticle of the lower and the upper epidermis, but are much more abundant in the former position.

It is apparent that the spread of rust hyphae is quite rapid once the leaf has become infected. This may be explained by the loose arrangement of the parenchyma cells in the hemlock leaf and by the facility with which the rust hyphae may run longitudinally beneath the cuticle (figs. 20 and 27). Hyphae pass with ease over the mid-vein from one side of the leaf to the other, but less readily beneath the mid-vein.

##### *Development of the Pycnia*

At irregular intervals in the sub-cuticular hyphae there appear areas in which the hyphae become more densely aggregated. Such an area is composed of more swollen and more septate hyphae than are found elsewhere at this stage. This is the early primordium of the pycnium (fig. 1). An area of basal cells is cut off from the hyphae, and each of these in turn gives rise to one or two pycniosporophores. There seem to be no paraphyses produced here, but flexuous hyphae appear, usually from the more central regions of the pycnium (fig. 2, f.h.). These may be readily distinguished by the fact that they are longer and more sinuous than the sporophores. Sometimes they are branched (fig. 9). In the

production of pycniospores, nuclear division takes place in the sporophore. A *small spindle may be observed at this time. Figures 3 and 4 show the spindle at anaphase. These figures give evidence of the presence of a centrosome at each pole of the spindle. Figure 5 shows a telophase spindle; while the tip of the sporophore is beginning to constrict. In figure 6 the nuclear division is complete, and one of the two nuclei has passed into the constricting tip, which will be cut off as a pycniospore. This pycniospore is shed before the next one is produced. Pycniospores are ellipsoid, each with a large dense nucleus and a scanty supply of cytoplasm (fig. 7).*

When the pycnium matures and begins to produce pycniospores, the pressure of the hyphae and spores causes the cuticle to rupture. Since the hyphae are longer near the center of the pycnium, more pressure is exerted upon the cuticle here than elsewhere. As a result, the cuticle is pushed up in a conical fashion and ruptures at its apex in an almost regular manner, so that the pycnium has a definite ostiole (fig. 2). It is through this ostiole that the pycniospores are extruded in a sticky secretion. Plate 12, fig. C, is a microphotograph of a mature sectioned pycnium.

There are some indications that pycniospores may fuse with flexuous hyphae, although no actual passage of a pycniospore nucleus into a flexuous hypha has been observed. Figure 8 shows what appears to be an empty pycniospore after fusion with such a hypha. Figure 9 is a group of flexuous hyphae, some of which show branching. One of the hyphae, only the tip of which is shown, has a group of pycniospores clustered about it.

### *Development of the Aecia*

The first indications of the appearance of the aecial primordium come before the pycnia have matured. These primordia at first consist of small aggregations of intermingled hyphae, which appear at rather regular intervals in the wing of the leaf on either side of the mid-rib. They are located slightly below the mid-region of the wing (figs. 56 and 57). The primordium is simply a region in the leaf where the hyphae undergo a more rapid growth, branching, intertwining, and becoming more septate than the surrounding hyphae. The primordium is by nature of its origin continuous with and a part of the whole branching system of hyphae in the leaf, including sub-cuticular hyphae, hyphae leading to and giving rise to the pycnia, and the hyphae passing between the parenchyma cells throughout the leaf. Stomatal hyphae, which are also a part of this system and may be traced to the aecial primordia, will be discussed more in detail later.

It should be remembered that the rust mycelium in the hemlock is a haplo-mycelium, with one haploid nucleus in each cell (figs. 1 and 2); whereas, many of the sections show that a number of the hyphae leading to the aecial primordia have cells with more than one nucleus (fig. 20). Such cells are not truly multi-nucleate, however, since the extra nuclei are constantly moving through the hyphae towards the primordia. There is good evidence that these nuclei have come into the hyphae through hyphal fusions within the leaf, fusions between pycniospores and flexuous hyphae, or through fusions between pycniospores and stomatal hyphae.

Figures 10-19 are mainly illustrations of hyphal fusions and nuclear migrations found in the hyphae just outside and leading into aecial primordia. Nuclei may pass through small pores in the cross walls of a hypha (figs. 12-14), or they may pass from one hypha into another through a fusion pore (figs. 10, 11, and 19). Figures 15-17 show an interesting method of hyphal fusion often found at the edges of the primordium. In this case, a hypha containing a nucleus attempting to pass into the primordium puts out a lateral protuberance into which the nucleus passes (fig. 15). This protuberance then fuses with a nearby hypha leading into the primordium, and the nucleus passes into the other hypha (figs. 16 and 17). Figure 18 shows one of the many nuclear divisions occurring in the aecial primordium during its development.

In addition to the probability that pycniospores fuse with flexuous hyphae, it appears that pycniospore nuclei may also enter by way of the stomatal hyphae (figs. 22-25). Figures 22 and 24 show stomatal hyphae, each with two nuclei. In figure 22 one of the two nuclei is moving through the hypha, as is indicated by its elongate form. Around the swollen tip of the hypha can be seen a cluster of pycniospores, two of which seem to have lost their nuclei. No actual passage of a pycniospore nucleus into a stomatal hypha has been observed by the writer, but this phenomenon is believed to be of frequent occurrence. Stomatal hyphae are very abundant in diseased leaves. In figures 23 and 25, the swollen and darkly staining hyphal tips have been killed by the closing of the stomata upon them.

As the web of hyphae composing the aecial primordium continues to grow in size, it becomes differentiated into two distinct regions (fig. 26). The outer area (towards the lower epidermis) is the plectenchyma, which consists of cells that increase in size and decrease in cytoplasmic content. The inner region is the developing hymenium and consists of cells that increase less in size, but more in cytoplasmic content (fig. 27). Eventually the cells of the plectenchyma, along with any host cells in this region, completely disintegrate. Plate 12, fig. A, is a microphotograph of the same aecial primordium illustrated by figure 27 in the drawings. This photograph shows the position of the primordium in the hemlock leaf and also three pycnia on the lower surface of the leaf. As may be seen here, the pycnia are quite near the primordium, and it is not at all difficult to find hyphae connecting the pycnia with the primordium. It is through such hyphae as these that the nuclear migrations already described were observed.

A study of the developing hymenial region of the primordium illustrated by figure 27 and Plate 12, fig. A, reveals some very interesting phenomena. A primordium at this stage shows various phases of cell fusion in the hymenium leading up to the formation of the aeciosporophores—the first truly binucleate cells to appear in the hemlock leaf. A slightly earlier stage than that shown in figure 27 reveals that the hyphae in the hymenial region have become arranged more or less parallel to one another, pointing from the base of the primordium towards the plectenchyma. Each cell is now enlarged and contains abundant cytoplasm and a single nucleus, which is quite expanded over its former size

(fig. 30). These rows of cells become rather closely packed together, so that a compact layer is formed at the base of the primordium.

During this growth, a number of hyphae running into the base of the primordium may be seen to contain nuclei which are still migrating into the developing hymenial region (figs. 28, 31-33). In figure 28, two nuclei are passing from cells of one hypha into a cell of another hypha through relatively large pores formed by cell fusions. Another nucleus is migrating through a cross wall. Figure 29 shows a nuclear division in one of the basal hyphae. Figures 31 and 32 show nuclei migrating into the hymenium through small pores in the cross walls. Figure 33 shows a nucleus passing from one basal hypha into another through a small fusion pore.

When pre-hymenial hyphae reach the stage shown in figure 30, cell fusions begin to take place. These fusions were always observed to occur between adjacent cells of adjacent hyphae, never between cells in the same hypha. Adams (2) calls these fusing cells gametes. The present writer, however does not consider them true gametes, since there is no nuclear fusion in the resultant fusion cell, but the two nuclei remain separate until fusion occurs in the teliospore on the alternate host. It is believed, nevertheless, that the nuclei of the two fusing cells do have opposite sexual attractions for one another and that all the nuclei in any pre-hymenial row of cells are of the same sex. Otherwise there is no apparent reason for the lack of fusions between cells in the same row. It appears likely that nuclei of different sexuality may begin to come into the aecial primordium from its very first appearance as a small group of intertwining hyphae, since these hyphae may be connected with pycnia of opposite sex, as is indicated by hyphal fusions already described for this stage. Other nuclei reach the primordium all during the process of its development by means of nuclear migrations, as already described.

Although nuclei of opposite sexual attractions are in constant association with one another in the developing primordium, they show no tendency towards pairing until cell fusions occur among the swollen pre-hymenial hyphae. Furthermore, it would appear that, in the course of development, the nuclei of different sexes become segregated into separate hyphae. The inclination for cell fusion to occur comes only after the cells have matured in size and cytoplasmic content to such an extent as is illustrated by figures 27 and 30.

In the aecial primordium illustrated by figure 27, cell fusions are in progress, and already a number of binucleate fusion cells have appeared. The width of the mature aecium is pretty well determined by the width of the primordium at this stage. Cell fusions begin towards the center of the primordium and proceed towards its periphery. Stages in cell fusion are illustrated by figures 34-37 and 42 and 43. Figure 34 shows a fusion cell shortly after fusion has begun. Fusion cells have been referred to by many investigators as "2-legged cells". In figure 34, however, it is a 4-legged cell. This character is entirely dependent upon the point at which the cells begin to fuse and the stage at which fusion is observed. As fusion proceeds, the fusion cell may lose altogether its 2-legged or 4-legged appearance and become a regular binucleate cell (figs. 42

and 43). Figures 35 and 36 show two binucleate 2-legged cells with fusion proceeding from the apex towards the base. Figure 37 shows a multiple fusion cell with four nuclei. These occur only rarely, but probably account for the aeciospores described by some investigators as containing more than two nuclei.

An interesting phenomenon following the production of fusion cells is the disintegration of all the potential fusion cells distal to them (figs. 35 and 36). These cells, which are termed pseudoplectenchyma, gelatinize and disintegrate, adding to the disintegrating plectenchyma of the young aecium (figure 27, ps.p.). Now, as is often the case, if fusions occur in the more distal cells of the pre-hymenial hyphae followed by, or simultaneous with cell fusions deeper in the pre-hymenium, the outer fusion cells and all the non-fused cells in the outer area gelatinize and add to the disintegrating plectenchyma. Evidently, this disintegration is tied up with the fact that all the food coming into the young aecium is brought in through the basal hyphae. The deeper cells, therefore, are the first to receive this food material, and when the deeper cells fuse they are stimulated to grow and become aeciosporophores, thus cutting off the food supply to the cells beyond them. Figure 42 shows two healthy fusion cells deeper within the pre-hymenium, while above them there are at least three fusion cells and several uninucleate cells degenerating. Figure 43 shows a row of young aeciosporophores shortly before they begin to produce spores. All the pseudoplectenchyma and plectenchyma cells are degenerating, thus clearing the way for spore production.

The first division of the aeciosporophore produces a peridial initial (fig. 44, p.i.). The peridial initial, in turn, divides to produce a peridial cell and a smaller intercalary cell. Figure 44 shows the beginning of nuclear division in the peridial initial, while nuclear division is in progress in the sporophore prior to the cutting off of the first aeciospore initial. During these developments the nuclei divide conjugately. Spindles are generally irregular and difficult to interpret at this time, although occasionally there are indications of the presence of definite chromosomes on the spindles.

Figure 45 shows the peridial initial already divided into a peridial cell (p.) and a small intercalary cell (i.p.), while the first aeciospore initial ( $a_1$ ) has been cut off and nuclear division is proceeding within it. Figure 46 reveals that the aeciospore initial has divided to produce a young aeciospore ( $a_1$ ) and a small intercalary cell (a.p.). A second aeciospore initial ( $a_2$ ) has been formed and another nuclear division is in progress in the sporophore to produce the third, and so on. Further stages in the development of the peridium show an increase in size and a decrease in protoplasmic content of the cells. The cell walls become rough and more thickened, while nuclei and cytoplasm degenerate completely (figs. 47-50). In rare cases it appears that an intercalary cell (figs. 47 and 48) or even the first aeciospore (fig. 48) may take part in the formation of the peridium.

As the peridial cells and aeciospores continue to grow in size and number, the pressure ruptures the lower epidermis of the leaf, the only remaining obstacle in its way. The peridium now extends itself to a considerable distance beyond

the lower epidermis, while the pressure of the spores on the inside causes it to rupture at its tip, making an opening through which the spores are shed (figs. 59 and 60). This outer peridium is quite delicate and is usually sloughed off in the sectioning and staining treatment.

Clearer mitotic figures were observed in hymenia of open aecia (figs. 51-55). Figure 54 indicates the presence of polar radiations, but these may have been artifacts. The spindle in figure 55 has two definite centrosomes, and the chromatin has the semblance of being composed of definite chromosomes.

The peripheral sporophores in the mature aecium do not form aeciospores, but are given over to the production of rows of lateral peridial cells, which are continuous with the earlier formed peridial cap (figs. 61-63). Peridial initials are cut off from the sporophores exactly as described for the aeciospores. The peridial initial, however, becomes divided by an oblique wall which cuts off an angular intercalary cell. This cell soon disintegrates and is thrown out of the peridial chain; while the peridial cells elongate and their end walls come together and adhere to form a continuous chain.

When the peridial cell is finally mature, it is apparently lifeless (fig. 64). Cytoplasm and nuclei have almost completely disintegrated, while the inside wall is much thickened and crenulate. The outside wall of the cell is much thinner and only slightly roughened.

One interesting feature not yet discussed is the fate of the intercalary cell. As soon as this cell is cut off from the spore initial it begins to gelatinize (fig. 65). This is indicated by the fact that its cytoplasm stains more darkly with gentian violet than that of the other cells. The writer has found that, as a general rule, gelatinization is indicated by a special affinity of the gelatinizing parts for gentian violet. This criterion almost invariably holds true with the safranin-gentian violet technique, but rarely with gentian violet as used in Gram's technique. In the latter case, the gelatin is apparently removed by the bleaching agent, oxalic acid.

Most of the gelatinization in the aecium takes place from the time the intercalary cell is first cut off until it becomes the third or fourth intercalary cell in the spore chain. During the process, this gelatin which is liberated from the disintegrating intercalary cells becomes spread about between the spore chains and takes an intensely blue stain with gentian violet. In figure 65, the gelatin between the chains is indicated by very dark strippling. However, it is not granular in nature, but appears as a homogeneous substance. It may also be observed in this figure that the lower intercalary cells are becoming quite vacuolate as they proceed towards disintegration.

Since most of the process of gelatinization occurs in the upper part of the aecium, it is not at all surprising that this upper area has, in sectional view, a banded appearance, indicating the extent of the gelatin (Plate 12, figs. B and D). These blue-stained bands had been observed earlier by the writer in a study of aecia in several *Gymnosporangium* species, but no specific importance was attached to them at the time. If Plate 12, fig. B, is again referred to, there can be seen within the darkly banded area a row of deeply stained intercalary cells

extending across the entire width of the aecium. It is in this region that they are undergoing the greatest amount of gelatinization.

It is quite possible that the sporophores may add to the gelatin content of the aecium, as the darker-staining tips of the sporophores would indicate (fig. 65). The intercalary cells of the peridial chains undergo the same gelatinization process as described for intercalary cells of the aeciospores (fig. 63). Here the gelatin appears on the outside of the aecium.

During or following the gelatinization of its contents, the intercalary cell in the spore chain elongates to resemble a stalk cell (figs. 66 and 67). Eventually the vacuolate cytoplasm within the cell becomes almost entirely depleted, the nuclei disintegrate, and the cell wall breaks down (fig. 67). The aeciospore is then free to fall out of the aecium.

Obviously, one of the main functions of the gelatin in the aecium is that of protection. Firstly, it may preserve a layer of moisture around the more delicate cells of the spore chain. Secondly, it can provide a lubricant about these more delicate cells, so that, as they slide past one another during development of the closely packed spore chains, they are not injured. A third possibility, and one about which least is known, is that the developing spore chain may obtain a certain amount of nourishment from the surrounding medium. The most rapid growth in the development of the aeciospore takes place in this area, and the intercalary cell is often pretty close to disintegration before the spore is mature.

The aeciospore has an interesting development, particularly with regard to its wall structure. Progressive thickening of the spore wall may be observed in the spore chains shown in figure 65. This is not a thickening of the outermost wall, or *perispore*, but is a second wall, the *epispore*, which appears just within the perispore (fig. 68). Since the spore is expanding in size during deposition of the epispore from within, the outer part of this wall, which was laid down first and now undergoes little or no further growth, begins to split (fig. 69). At this stage, perispore can be distinguished from epispore. By the time the aeciospore attains its maximum size, the perispore has reached the limit of its elasticity. It becomes ruptured and is eventually sloughed off entirely, exposing the deeply crenulate epispore.

During this development, there is a spot at each end of the spore where the epispore is not laid down (figs. 68 and 69). These thin spots appear in the aeciospore wall opposite its two points of attachment to the intercalary cells. There is an elongate smooth area down one entire side of the spore where the epispore is very thin or entirely absent. Figure 71 shows this elongate thin area on one side of the spore in longitudinal section, while figure 72 shows it in cross section. These latter two figures show the appearance of the third and innermost spore wall, the *endospore*. It appears at about the time the aeciospore is shed and remains rather thin. Most of the figures show that the spore contains an abundant supply of vacuolate cytoplasm, the densest part of which is a peripheral layer just within the developing spore wall. Two moderately expanded nuclei with distinct nucleoli are located near the center of the cell. The thin



spots at each end of the spore are germ pores. It is not certain whether germination may occur through the lateral thin area, but the position of the germ tube on the aeciospore illustrated in figure 73 would indicate that this is probable.

### *Haustoria and Host-Parasite Relationships in the Hemlock*

Examination of cells in infected hemlock leaves revealed the presence of numerous haustoria. These are typically elongate structures with short lateral branches or lobes (figs. 38-41). Each haustorium has a single nucleus (figs. 40-41) and is very narrow at the point where it penetrates the cell wall (figs. 38 and 39). The haustorium is frequently in contact with the host nucleus and definitely shows an affinity for starch grains in the host cell. Figures 38 and 40 show the haustorial lobes partly enveloping a number of starch grains, while most of the starch in the cell shown in figure 39 has been completely broken down and utilized by the parasite. This figure should be compared with the healthy cells in figure 21.

The extent of starch hydrolysis by the rust fungus is quite striking. Plate 12, fig. E, is a photograph of a sectioned hemlock leaf with an aecium on one side, while the last aecium has already been passed in sectioning on the other side. The less infected wing of the leaf shows numerous starch grains, staining purple with gentian violet, while the wing containing the aecium has conspicuously fewer starch grains.

The parasite causes a moderate degree of hypertrophy in the hemlock leaf, so that the host cells are somewhat larger than their normal size and the leaf as a whole becomes more thickened and irregular in outline (Plate 12, fig. A).

During the course of this study, the question arose as to why the aecia were so regularly spaced in a single row on either side of the mid-rib (fig. 59). The explanation is based upon the method of infection and upon spatial and food relationships. First, a re-examination of the figures will show that an aecium is located at about the widest portion of the wing and that there is hardly space for another aecium in the same section of the wing. Secondly, because of the facility with which infecting hyphae may spread rapidly through the leaf early in development, aecia may develop on both sides of the mid-rib and along the entire length of the leaf at about the same rate. Furthermore, the tendency is apparently towards the production of as many aecia as possible without interference in food relationships between them. Thus, the equal spacing in the leaf.

### *Infection of the Hydrangea and the Development of the Uredinium*

Only a few stages in the initial infection of hydrangea leaves by the aeciospores have been observed. Aeciospores produce infection hyphae which enter through the stomata and then branch out within the leaf (figs. 73-75). These branching hyphae soon come into contact with the mesophyll cells and send haustoria into them (fig. 76). The hyphae are septate at irregular intervals and hyphal cells are binucleate. Likewise, the haustoria are binucleate. The haustorium is typically a pyriform or reniform swelling at the end of a narrow stalk, which is even more narrow at the point where it penetrates the host cell wall (figs. 77-80).

*It arises from an intercellular hypha at a point where the latter is pressed closely against the host cell. In some of the older cells, where the plasma membrane had become warped in places, it could be seen that the haustorium does not penetrate the plasma membrane but invaginates it (figs. 77 and 79).*

Vegetative hyphae in the hydrangea leaf are considerably larger than those in the hemlock leaf, but are never found in large numbers until the appearance of the uredinal primordia. At this time hyphae begin to aggregate in groups near the lower epidermis. These hyphae become more septate and give rise to upright and expanded binucleate cells which, at their tips, come into contact with the lower epidermis (fig. 81). The two nuclei in each of these cells are large and contain conspicuous nucleoli, while the cytoplasmic contents of the cell are quite dense and minutely vacuolate. This layer of binucleate cells constitutes the early hymenium of the uredinium. Its further development will be discussed more in detail. Figure 82 is a section through a young uredinium at a stage shortly after division has begun in the sporophores. As in the aecium, development proceeds from the center towards the outside. In fact, new sporophores are being added all along around the sides of the sorus.

As in the aecium, the first division of the sporophore produces a peridial initial (figs. 83 and 84). The inner cell is called the basal cell. During this development, nuclei divide conjugately, although the two spindles may not be at exactly the same stage of division (fig. 83). Polar radiations are occasionally observed. The peridial initial now divides to form a large peridial cell and a small intercalary cell (figs. 84-86). Figure 84 indicates the presence of centrosomes, as well as polar radiations, during nuclear division. The peridial cell quickly becomes vacuolate and its nuclei begin to degenerate (figs. 85-87, 92), while the intercalary cell degenerates completely.

The basal cell may now do one of two things. It may divide first to produce a uredospore initial (figs. 86 and 87), or it may produce a bud which in turn divides to form a uredospore and an intercalary cell (figs. 85, 91-93), the latter method being much the more common. In figure 86, a uredospore initial has been cut off from the basal cell, and in figure 87, nuclear division is apparently taking place in the initial. A bud, however, is being produced by the basal cell, and the small uredospore initial will probably disintegrate before division is completed. Figure 94 shows a uredospore initial just beginning to degenerate. In the material examined, few spores could be definitely ascertained to have come from these uredospore initials. Figure 88 shows a uredospore possibly derived in this manner.

The basal cell generally begins to bud just after the peridial initial divides (figure 85). Early disintegration of the peridial intercalary cell allows for this growth. The nuclei in the basal cell divide conjugately and send a pair of nuclei into the bud (fig. 91). This bud becomes separated from the basal cell by a cross wall (fig. 92), and a conjugate nuclear division occurs in the bud, which then divides to form a binucleate uredospore supported by a binucleate stalk cell (figs. 93 and 95). The stalk cell becomes elongate and, unlike the intercalary cell of the peridium, is persistent (figs. 93, 99 and 100).

There appears to be no definite number of buds which may be produced by a basal cell. One or several may be formed, depending upon the amount of cytoplasm that the basal cell is able to maintain.

After the peridial cells are produced, they elongate in a vertical plane, while their adjacent walls adhere to form one continuous peridium (fig. 104). As the protoplasmic contents of these cells degenerate, their walls, particularly the outer one, thicken (figs. 95, p, and 105, a.p.). Occasionally, during earlier development in the uredinium, a bud may force its way in between the peridial cells and enter directly into the formation of the peridium without dividing (fig. 98). Growth of the uredinium causes the epidermis of the leaf to rupture, and pressure from within the uredinium causes the peridium to burst open, allowing the spores to be discharged. Plate 12, fig. G, shows a mature uredinium just before opening. The peridium ruptures at the apex because there is more pressure at that point. Spores are shed through the opening, which is at first rather regular and ostiolar in appearance. There are, however, no especially modified ostiolar cells, as have been described by other investigators for related forms.

When the uredinium has completed its lateral expansion within the leaf, the last three or four rows of sporophores to appear at the sides of the sorus become peridial in nature, and their protoplasmic contents degenerate (fig. 105, l.p.). Their cell walls thicken somewhat, but never become as thick as those of the apical peridium (fig. 105, a.p.).

The mature uredospore, when discharged from the uredinium, has a very spiny wall and about 6 or 7 germ pores (fig. 103). The history of wall formation in the uredospore is quite interesting. Very early in the development of the spore, the cytoplasm just within the perispore wall assumes a regularly reticulated appearance. This effect is illustrated in figure 90, which is a surface view of the young spore. There are apparently a large number of little hemispherical hyaline areas in the cytoplasm which give it this effect, as can be seen in figure 89, a longitudinal section through the spore. The cytoplasm adjacent to these hyaline areas is denser than elsewhere in the cell. Although, with the staining methods used, no visible contents could be seen in the hyaline spots, they are evidently not vacant, since a slightly later stage will show that the spines are forming in them (fig. 96). These spines penetrate the perispore. While this is happening, the dense peripheral layer of cytoplasm lays down more cell wall material between the spines (fig. 97), and eventually the wall is evened out on the inside (fig. 101). There are, however, certain spots in which the episore is not formed. These become the germ pores of the spore (figs. 101 and 103). The wall bearing the spines is called the episore.

A third wall is now laid down just within the episore. This is the endospore (fig. 102). It does not become as thick as the fore-mentioned wall. The perispore here, unlike that in the aeciospore, is persistent and remains closely applied to the spore as its outermost wall. The spines, moreover, appear to be emanating from this outer wall; whereas, actually they are penetrating it. This could be determined only in well-stained sections of mature uredospores, in which the perispore stains with gentian violet and the other two walls remain unstained (fig. 102).

Uredospores reinfect the hydrangea throughout the latter part of the summer. Their spines are well adapted for securing their attachment among the hairs on the lower surface of the leaf. The uredospore produces a germ tube which enters the stoma (figs. 106-109). Upon entering the stoma, the germ tube becomes lobed into a number of little swellings, or sub-stomatal vesicles. Nuclear division is rapid during their formation and each lobe is binucleate (fig. 109). The lobes now give rise to hyphae which penetrate the leaf in all directions (fig. 108). In figure 109, two germ tubes have entered the same stoma. The hyphae now go on to infect the leaf in the manner already described for aeciospore infections.

#### *Development of the Teliospores in Hydrangea*

So far, infection in the hydrangea leaf has been confined almost entirely to the spongy tissue. However, towards the latter part of the growing season, hyphae running along more or less horizontally beneath the palisade layer give rise to upright swollen hyphae that push up between the palisade cells to the upper epidermis (fig. 110). The vertical hypha receives a rich supply of cytoplasm and two nuclei, which become quite expanded and contain conspicuous nucleoli. Upon reaching the cell wall of an upper epidermal cell, the vertical hypha penetrates it with an apical papilla (fig. 111), which expands immediately upon entering the cell (fig. 112). The papilla evidently enters by dissolution of the cell wall, since there is no indication of pressure being exerted on the cell wall by its relatively blunt tip. The vertical hypha is much broader at its point of entry into a cell than is the haustorium.

As the globular swelling of the hypha within the epidermal cell continues, the two nuclei and most of the cytoplasm in the vertical hypha pass into it (figs. 112-114). In transit, the nuclei become drawn out into very fine threads as they pass through the constriction in the hypha. The nuclear membrane remains intact during the process and expands within the swelling, while decreasing in size in the lower part of the hypha. The chromatin in the lower portion of the nucleus streams around the periphery of the membrane and passes upwards through the constriction to redistribute itself in fine strands radiating about the periphery of the expanding membrane within the swelling (figs. 112 and 114). The binucleate swelling is the teliospore initial (fig. 115).

While the teliospore initial continues to expand, the two nuclei divide conjugately and the initial divides into two binucleate cells (figs. 116-120). Spindles in dividing teliospore initials are usually in a plane parallel with the leaf surface. Figures 116 and 117 show anaphase spindles with small centrosomes and fairly distinct chromosomes. The telophase in figure 118 shows four distinct, though abnormally expanded, chromosomes at each pole. Figure 119 reveals the presence of polar radiations at the spindle tips. In figure 120, spindle fibers can be made out between the reorganizing nuclei, and the vertical cross wall is being laid down across the path of these fibers. Apparently, the fibers take part in the formation of the cross wall.

Like the haustorium, the teliospore initial invaginates the plasma membrane and does not penetrate it. This is indicated in figure 121, where the plasma membrane is, in places, warped away from the wall of the teliospore initial.

In rare instances an initial may become a single-celled teliospore, but more often it becomes a teliospore with 2-8 cells, the most common number being 4. Several initials usually enter the same epidermal cell.

Each cell of a maturing teliospore contains abundant cytoplasm and two rather expanded nuclei with distinct nucleoli (fig. 122). The spore wall now begins to thicken, with the exception of a small germ pore at the top (fig. 124). Coincident with thickening of the wall is the fusion of the two nuclei in each cell (figs. 123-128). First, the chromatin in each nucleus condenses into a spireme-like structure, or possibly into several dense strands. The nuclear membrane now seems to break down entirely, and chromatin threads from the two nuclei begin to intermingle (figs. 124 and 125). The chromatin of both nuclei becomes redistributed and combined into a single large fusion nucleus (figs. 126-128). The fusion nucleus now produces a new nuclear membrane and contains a single nucleolus.

In figure 129 can be seen a multicellular teliospore derived from a single initial. One cell has been cut off by an oblique wall. The spore walls have thickened, and the nuclei are just ready to fuse. Plate 12, fig. F, is a photograph of a prepared section through a hydrangea leaf and shows a row of teliospores in the upper epidermis.

Sometimes teliospores are produced atypically in cells other than those of the upper epidermis. Figure 130 shows a teliospore in a lower epidermal cell. In this case there is no swollen vertical hypha on the outside, but a couple of empty hyphae only slightly larger than ordinary vegetative hyphae, may be seen. Figures 131 and 132 illustrate what happens when the upper epidermal cells are already crowded with developing teliospores and the epidermal cell walls have become thicker. The tardy initials have entered palisade cells, and the teliospores are developing there. The dark areas in the figures represent regions which stained excessively with gentian violet and probably indicate a gelatinization of the host cell. Figure 133 shows the margin of an old uredinium in which teliospores have formed. It is not known whether these spores were formed within the walls of the old uredinal cells or whether they represent converted uredinal cells.

A few supplementary data have been collected on teliospore development in the related species, *Thekopsora vacciniorum*. Teliospores were found abundantly in both the lower and the upper epidermal layers in leaves of its ericaceous hosts, although Arthur (3) reports them as being only hypophyllous. Nuclear divisions in teliospore initials were observed, and spindles were found to have distinct polar radiations, while the number of chromosomes was four (figs. 134 and 135). These data correspond well with the data obtained for *T. hydrangeae*. Figure 136 shows a teliospore in a lower epidermal cell prior to nuclear fusion. Note the relatively small size of the hypha which produced the teliospore initial.

### *Basidia*

Hydrangea leaves containing teliospores were kept over-winter in a moist place in our cold room. All attempts to germinate the spores before spring were

unsuccessful. Teliospores began to germinate on May 27, after being placed in a moist chamber at room temperature. Regular 4-celled basidia were produced.

Upon germination, each teliospore cell begins to extrude its contents through the apical pore. The young promycelium penetrates the epidermal cell wall and cuticle, and the entire protoplasmic contents of the teliospore cell pass into it (fig. 137). The nucleus enters into prophase (fig. 137) and the first meiotic division takes place (fig. 138). The two nuclei produced may go through a short resting phase (fig. 139) but soon undergo the second meiotic division (figs. 140 and 141). Distinct chromosomes may be defined on some of the spindles.

These two divisions result in a 4-celled basidium, each cell of which produces a sterigma into which the cytoplasm and a single haploid nucleus pass (figs. 142 and 143). As the sporidium forms at the tip of the sterigma, nucleus and cytoplasm pass into it (fig. 145). The chromatin of the nucleus becomes more condensed and draws out into a very thin strand as it passes from the sterigma into the sporidium.

The nucleus, after having entered the sporidium, begins to divide (fig. 146). This division is completed before the sporidium is discharged, and one of the two nuclei almost immediately begins to degenerate (fig. 147). The sporidium is discharged in the binucleate condition (fig. 148), but one of the two nuclei continues to degenerate, while the other expands. Figure 144 shows a group of basidia drawn from live material. The sporidia are the spores which infect the hemlock.

#### DISCUSSION

Aside from a limited account by Dodge (8) on the uredinium of *Thekopsora hydrangeae*, practically no research has been done on this species of rust. Although several isolated works have been carried out on the various sori in the genus, no one has produced anything on the complete life history of any representative in the group, and there have been a number of questions on development in need of clarification. The present work clarifies some of these points and presents new ones to be considered.

The discovery of the production of a gelatinous layer in the aecium, chiefly by disintegration of the intercalary cells, appears to be new for the rusts. The intercalary cells, which eventually elongate and look like true stalks, simulate the very gelatinizable stalk cells of the teliospores of *Gymnosporangium*. The writer has also observed a similar process in *Gymnosporangium* aecia. Intercalary cells and stalk cells are homologous structures, since they are both modified spores.

Nuclear migrations into the base of the aecial primordium, as described in this paper, are similar to those described by Christman (6) for *Phragmidium speciosum* Fr. and *Caeoma nitens* S. In the primordia, he found a fusion of what he called equal "gametes." Blackman (5) describes for *Phragmidium violaceum* Wint. a migration of nuclei into the primordium through small pores in the cell walls. In this case, however, the migrating nucleus enters directly into the basal cell without cell fusion. This latter method of establishing the binucleate condition was not observed in *Thekopsora hydrangeae*.

The present writer has found that, although there are abundant nuclear migrations into the aecial primordium, no truly binucleate cells are found until fusion occurs between cells of adjacent rows of pre-hymenial hyphae. Such cells have been referred to by Adams (2), Christman (6), and others as gametes, but they are apparently not true gametes, since nuclear fusion does not occur in the resultant fusion cell. Arthur (4) refers to the hyphae in which fusion takes place as "gametophytic hyphae" and calls the cells which fuse "cells of the fertile part of the primordium." Gäumann and Dodge (9) and Colley (7) refer to these last-mentioned cells as "fertile cells." The present writer uses the term *pre-hymenial hyphae* in preference to Arthur's "gametophytic hyphae," since all of the hyphae in the hemlock leaf may be considered gametophytic. It seems probable that, in the development of the pre-hymenial hyphae, sexual segregation of nuclei may take place so that cells of adjacent hyphae contain nuclei of opposite sexual attraction. Fusions were never observed between two cells in the same hypha, but they did occur often at more than one level in the same pair of hyphae.

Dodge (6) believed that the spore initials in the uredinium of this rust were cut off directly from the basal cells without the budding process, and that uredospores were produced in a manner approaching the catenulate arrangement. The present writer finds that by far the majority of spores are produced by budding of the basal cell, and that the spores are not catenulate in arrangement. Dodge's contention that the intercalary cells in the uredinium are sacrificed to furnish food for the developing uredospores is interesting. The present study of the aecium of *Thekopsora hydrangeae* has indicated even more convincingly that such is probably the case in relationships between the aeciospore and its intercalary cell. In a paper following that of Dodge, Moss (12) indicates, in a brief description of the uredinia of *Thekopsora vacciniarum*, that uredospores are formed mainly by budding of basal cells. This is in agreement with the findings given in the present paper.

Ludwig and Rees (11), Dodge (8), and Moss (12) have described the uredinial peridia of various species of *Pucciniastrum* as possessing especially modified ostiolar cells with much thickened walls and often with spines. In *Thekopsora hydrangeae*, the cells around the ostiole are neither spiny nor unduly thickened and are not different from the other peridial cells.

The two common types of uredinia are those with a peridium, characteristic of the lower groups of rusts, and those without a peridium, characteristic of the higher groups. The uredinium of *Thekopsora hydrangeae* is of the former type, but differs from the uredinia of its related species in having no especially modified ostiolar cells, and with more persistent cells supporting the uredospores. These latter cells, therefore, resemble the stalk cells of the non-peridial forms and are an advancement over the more ephemeral intercalary cells found in many peridial forms. Thus the uredinium of *T. hydrangeae* affords a transitional step in the progression from lower to higher forms.

Uredospores, as well as aeciospores, were found to possess three walls, which are of rather similar origin for both spores. Lohwag (10) also observed the three

walls in uredospores of *Uromyces Erythronii*. Sappin-Trouffy (14) illustrated this three-walled condition for various types of spores in several different rusts. Upon examination of the wall of a young aeciospore of *Peridermium Pini*, he reported the presence of polygonal thickenings from which the spines appear. These are undoubtedly identical with the spine-forming hyaline areas observed by the writer beneath the perispore in the uredospore of *T. hydrangeae*.

Pady (13) recently described teliospore development in various genera of the *Pucciniastreae*, including *Thekopsora vacciniorum*. The rather peculiar type of nuclear fusion observed by the present writer for *T. hydrangeae* was briefly touched upon by Pady in a study of *Pucciniastrum epilobii* (Pers.) Otth. and *Hyalopsora aspidiotus* (Pk.) Magn. He states that "At first the two nuclei are small and homogeneous, but as they move together the chromatin is heavily staining and each nucleus has an irregular outline. The fusion nucleus is often to be seen in the spireme stage. . . ." The present findings on *Thekopsora hydrangeae* also reveal that the nuclei are probably in the spireme stage before fusion and that the nuclear membranes are broken down, a new one appearing in the fusion nucleus.

From studies of dividing teliospore initials, it appears that the chromosome number for this rust is 4. This count could not be accurately made in the developing basidia, because of a limited amount of material showing meiotic divisions. Sappin-Trouffy (14), in a study of germinating teliospores of *Thekopsora arcolata* Wallr., reports the chromosome number as 2. This number was repeatedly given by Sappin-Trouffy for most of the rusts studied by him, and it is probably the result of a misinterpretation of the characteristic bilobed mass of chromatin at each end of the telophase spindle.

#### SUMMARY

1. Pycnia of *Thekopsora hydrangeae* Magn. are subcuticular in origin, occurring in the spring on both surfaces of the leaves of *Tsuga canadensis*, but more commonly on the lower surface.

2. Aecial primordia appear in the leaf as tangled wefts of hyphae on either side of the midrib. Nuclear migrations towards and into the primordium are common during its development.

3. The primordium becomes differentiated into an outer sterile region of plectenchyma and an inner pre-hymenial area. Cell fusions occur in the latter, and a hymenium of binucleate aeciosporophores is produced.

4. The aeciosporophores cut off first a peridial cap and then aeciospores, while the plectenchyma disintegrates. Intercalary cells are formed in the production of peridial cells and aeciospores.

5. Intercalary cells disintegrate to produce a protective gelatinous layer around the upper parts of the spore chains. This gelatin may also have some nutritive value.

6. A row of mature aecia with long cylindrical peridia breaks through the lower epidermis of the leaf on either side of the midrib.



7. Mature aeciospores are binucleate and possess thick, rough walls. During growth they develop three walls, the outermost disappearing at maturity.

8. Haustoria in the hemlock leaf are elongate and lobed uninucleate structures with an affinity for starch grains.

9. Aeciospores infect the hydrangea in early summer. Their germ tubes penetrate the leaf stomata and produce intercellular mycelia with binucleate cells and small reniform or pyriform, intracellular haustoria that are binucleate.

10. Uredinia develop from compact groups of swollen vertical hyphae which appear next to the lower epidermis. A compact peridium is formed, and uredospores with stalk cells are produced mainly by budding of the basal hymenial cells. Uredospores develop three walls, all of which persist in the mature spore.

11. Mature uredinia rupture the lower epidermis to expel spores which re-infect the hydrangea during the latter part of the summer. Their germ tubes penetrate the stomata.

12. In late summer and early fall, swollen vertical hyphae push up between palisade cells to the upper epidermis and give rise to binucleate intracellular teliospore initials. A single epidermal cell may receive several initials, and each initial generally becomes divided into a 2-8-celled teliospore.

13. Observations upon dividing nuclei in the teliospore initial reveal the presence of 4 chromosomes for the haploid number in this rust. The same number was found in *Thekopsora vaccinatorum*.

14. When the teliospore initial ceases to divide, the wall of the teliospore begins to thicken, while the two nuclei fuse. During fusion, the chromatin of each nucleus condenses into a spireme-like structure and the nuclear membrane breaks down. A new nuclear membrane is formed in the fusion nucleus.

15. Teliospores overwinter in fallen hydrangea leaves to germinate the following spring and produce regular 4-celled basidia. Each basidium gives rise to 4 sporidia. The sporidia infect the hemlock.

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## EXPLANATION OF PLATES

### PLATE 5

- Fig. 1. Young pycnium. Position of cuticle, removed during staining procedure, indicated by dotted line. (b.c., basal cell; p., pycniosporophore.)  $\times 825$ .
- Fig. 2. Mature pycnium. (f.h., flexuous hypha.)  $\times 1216$ .
- Figs. 3-6. Pycniosporophores, showing nuclear divisions leading up to pycniospore formation.  $\times 1216$ .
- Fig. 7. Pycniospores with large, dense nuclei.  $\times 1216$ .
- Fig. 8. Flexuous hypha with pycniospore apparently fused to it.  $\times 1216$ .
- Fig. 9. Group of flexuous hyphae in a pycnium. Note cluster of pycniospores about the tip of one of the hyphae.  $\times 1216$ .
- Fig. 10. Hyphal fusion and nuclear migration. Found near center of hemlock leaf about midway between two pycnia, one on the lower and the other on the upper surface of the leaf.  $\times 1216$ .
- Fig. 11. Spiral-shaped nuclei migrating from one hypha into another, following hyphal fusion. Found in a very early primordium of only a few intertwined hyphae.  $\times 1216$ .
- Fig. 12. Nuclear migration through cell wall of hypha leading from pycnium to aecial primordium.  $\times 1216$ .
- Figs. 13-14. Nuclear migrations through cell walls in hyphae found at edge of aecial primordium.  $\times 1216$ .
- Fig. 15. Hypha producing a small fusion papilla. Found at edge of aecial primordium.  $\times 1216$ .
- Figs. 16-17. Nuclei passing through fusion papillae from one hypha into another. Found at edge of aecial primordium.  $\times 1216$ .
- Fig. 18. Nuclear division in primordial hypha.  $\times 1216$ .
- Fig. 19. Fusing hyphae and nuclear migration, found in early aecial primordium.  $\times 1216$ .
- Fig. 20. Pycnium and aecial primordium.  $\times 360$ .
- Fig. 21. Normal cells of hemlock leaf. Shows starch grains, cytoplasm, and nucleus.  $\times 540$ .
- Figs. 22-25. Stomatal hyphae.  $\times 825$ .

## PLATE 6

- Fig. 26. Aecial primordium, showing the region of plectenchyma just appearing.  $\times 360$ .  
 Fig. 27. Pycnia and aecial primordium with developing hymenium. Plectenchyma is just before disintegrating. (b.h., basal hypha; ps.p., pseudo-parenchyma; st.h., stomatal hyphae.)  $\times 360$ .  
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- Figs. 40-41. Haustoria. Note affinity of haustorium for starch grains.  $\times 825$ .  
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## PLATE 8

- Figs. 57-58. Outline sketches of diseased hemlock cells in cross section, showing position of pycnia and aecia on either side of the midrib.  $\times 45$ .  
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 Figs. 61-63. Development of outer sporophores of aecium into peridial cells and angular intercalary cells which degenerate.  $\times 825$ .  
 Fig. 64. Mature peridial cells.  $\times 1216$ .  
 Fig. 65. Spore chains showing gelatinization of intercalary cells. (Dark stippling indicates extent of gelatin in this region.) Note also progressive thickening in aeciospore walls.  $\times 825$ .  
 Fig. 66. Aeciosporophores showing gelatinization of intercalary cells and their subsequent elongation into stalk-like cells.  $\times 825$ .  
 Fig. 67. Disintegration of the stalk-like intercalary cell.  $\times 825$ .  
 Fig. 68. Young aeciospore showing secondary wall thickening.  $\times 1216$ .

- Fig. 69. Aeciospore with the thick secondary wall or episore, cracking and becoming distinguishable from the outer wall, or perispore.  $\times 1216$ .
- Fig. 70. Aeciospore with perispore rupturing and sloughing off from the episore.  $\times 1216$ .
- Fig. 71. Aeciospore sectioned longitudinally so as to show smooth elongate hilum on one side. Perispore has disappeared, while a tertiary thickening, the endospore, has appeared within the episore.  $\times 1216$ .
- Fig. 72. Transverse section of aeciospore, showing endospore, rough episore, and position of hilum.  $\times 1216$ .
- Figs. 73-75. Aeciospore infection hyphae penetrating stomata of the hydrangea leaf.  $\times 825$ .
- Fig. 76. Rust hypha in hydrangea leaf, showing haustoria within host cells.  $\times 825$ .

## PLATE 9

- Figs. 77-80. Typical binucleate haustoria in hydrangea leaf cells. Note that the plasma membrane of the host cell is invaginated and not penetrated by the haustorium.  $\times 1216$ .
- Fig. 81. Uredinial primordium, showing early appearance of the swollen, binucleate vertical hyphae, bounded by the lower epidermis.  $\times 825$ .
- Fig. 82. Early divisions of the vertical hyphae in the young uredinium.  $\times 825$ .
- Fig. 83. Vertical hypha undergoing its first division. Note polar radiations.  $\times 1216$ .
- Fig. 84. Peridial initial and basal cell produced by first division of vertical hypha. Note polar radiations from the spindle of the dividing nucleus in the peridial initial.  $\times 1216$ .
- Fig. 85. Elongate and vacuolate peridial cell with its small intercalary cell; also budding basal cell. (b., bud.)  $\times 1216$ .
- Fig. 86. Uredospore initial cut off from basal cell. (h.c., basal cell; u.i., uredospore initial; i., peridial intercalary cell; p.c., peridial cell.)  $\times 1622$ .
- Fig. 87. Uredospore initial apparently beginning to disintegrate during nuclear division; basal cell has produced a large bud (b).  $\times 1216$ .
- Fig. 88. Uredospore with flattened intercalary cell.  $\times 1216$ .
- Fig. 89. Section through young uredospore, showing the typical dense cupulate cytoplasmic layer just within the perispore.  $\times 1216$ .
- Fig. 90. Surface view of young uredospore, showing the hyaline spots in the cytoplasm just within the perispore.  $\times 1216$ .
- Fig. 91. Conjugate division in the basal cell during the formation of a bud.  $\times 1216$ .
- Fig. 92. Basal cell with bud cut off by a cross wall.  $\times 1216$ .
- Fig. 93. Basal cell with bud dividing to form uredospore and stalk cell; also shows a stalk after uredospore has been shed.  $\times 1216$ .
- Fig. 94. Uredospore initial disintegrating after having been cut off directly from basal cell.  $\times 1216$ .

## PLATE 10

- Fig. 95. Young uredospore and stalk cell; portion of peridium (p), with thickening cell walls, above.  $\times 1216$ .
- Fig. 96. Section of uredospore wall, showing the spines beginning to penetrate perispore.  $\times 1216$ .
- Fig. 97. Section of uredospore wall, showing spines becoming a part of the developing episore.  $\times 1216$ .
- Fig. 98. Bud from basal cell becoming a part of the peridium.  $\times 1216$ .
- Figs. 99-100. Basal cells which have produced two uredospores each. Note stalks with finely granular cytoplasm and disintegrating nuclei.  $\times 1216$ .
- Fig. 101. Section through uredospore, showing the mature episore with spines penetrating the perispore. Note germ pore at one end.  $\times 1216$ .

- Fig. 102. Portion of mature uredospore wall, showing the presence of a third wall, the endospore. Note that perispore persists.  $\times 1216$ .
- Fig. 103. Surface view of mature uredospore, showing position of germ pores and spines.  $\times 1216$ .
- Fig. 104. Uredinium at about the time of maturation of the first spores.  $\times 540$ .
- Fig. 105. Edge of a mature open uredinium, showing point of juncture between apical peridium (a.p.) and lateral peridium (l.p.).  $\times 825$ .
- Figs. 106-9. Infection hyphae of the uredospores. Note characteristic sub-stomatal vesicles.  $\times 825$ .
- Fig. 110. Vertical hyphae pushing up between palisade cells to upper epidermis.  $\times 1216$ .

## PLATE 11

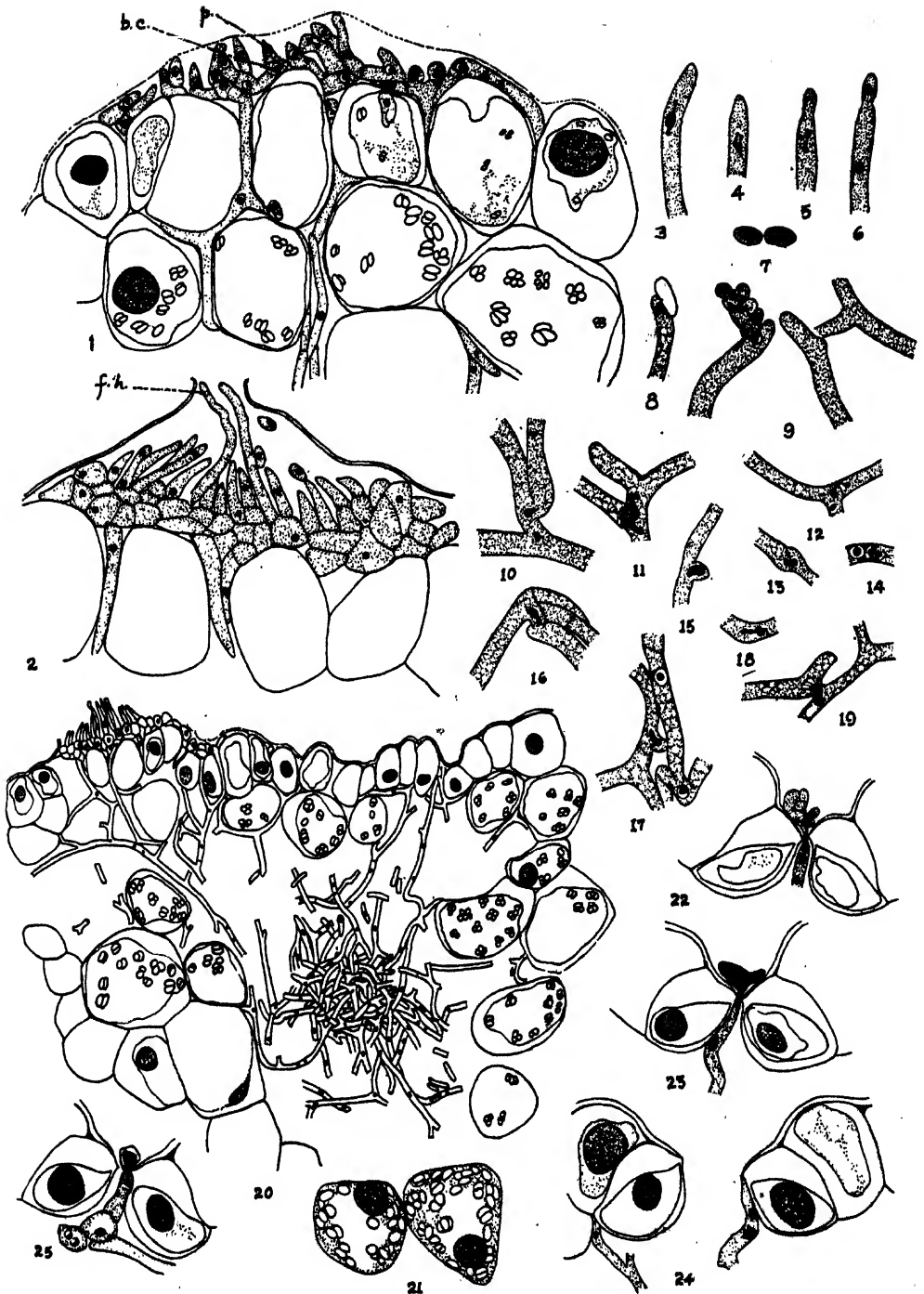
- Fig. 111. Vertical hypha penetrating epidermal cell wall.  $\times 1216$ .
- Figs. 112-113. Teliospore initial expanding within epidermal cell and receiving the two nuclei.  $\times 1216$ .
- Fig. 114. Two teliospore initials forming in the same epidermal cell.  $\times 1216$ .
- Fig. 115. Binucleate teliospore initial in epidermal cell; also a binucleate vertical hypha.  $\times 1216$ .
- Figs. 116-117. Anaphase nuclei in teliospore initials.  $\times 1216$ .
- Fig. 118. Early telophase, showing four expanded chromosomes at each pole. Note wall appearing across middle of spindle.  $\times 1216$ .
- Fig. 119. Telophase with polar radiations.  $\times 1216$ .
- Fig. 120. Late telophase following conjugate nuclear division in teliospore initial. Note cell wall appearing across middle of spindle fibers.  $\times 1216$ .
- Fig. 121. Teliospore initial, showing plasma membrane of host cell invaginated around it.  $\times 1216$ .
- Fig. 122. Binucleate teliospore cell with thickened walls.  $\times 1216$ .
- Figs. 123-127. Nuclear fusion in the teliospores.  $\times 1216$ .
- Fig. 128. Teliospore cell with a single fusion nucleus.  $\times 1216$ .
- Fig. 129. Section through a multicellular teliospore in an epidermal cell at about the time that nuclear fusion begins.  $\times 540$ .
- Fig. 130. Teliospore in lower epidermis.  $\times 825$ .
- Figs. 131-132. Abnormal development of teliospores in palisade region. (Dark inking indicates gelatinization of cells.)  $\times 825$ .
- Fig. 133. Abnormal development of teliospores in outer region of uredinium.  $\times 825$ .
- Fig. 134. *Thekopsora vacciniarum*. Teliospore initial, showing dividing nuclei and polar radiations.  $\times 825$ .
- Fig. 135. Same. Teliospore initial with dividing nucleus, showing the presence of four chromosomes at each pole and polar radiations.  $\times 825$ .
- Fig. 136. Same. Group of binucleate teliospore cells in lower epidermal cell of leaf of *Azalea*.  $\times 540$ .
- Fig. 137. Teliospore of *Thekopsora hydrangeae* producing a promycelium. Nucleus in prophase.  $\times 1216$ .
- Fig. 138. First meiotic division in the promycelium.  $\times 1216$ .
- Fig. 139. End of first meiotic division. Nuclei in brief resting stage.  $\times 1216$ .
- Figs. 140-141. Second meiotic division. One spindle is obliterated in the latter figure.  $\times 1216$ .
- Figs. 142-143. Four-celled basidia, producing sterigmata.  $\times 1216$ .
- Fig. 144. Live basidia producing sporidia.  $\times 540$ .
- Fig. 145. Sterigma with sporidium forming at the tip. Notice the attenuation of the nucleus as it passes into the sporidium.  $\times 1216$ .
- Figs. 146-147. Nuclear division in the sporidia just before the latter are discharged.  $\times 1216$ .
- Fig. 148. Binucleate sporidium with one of the two nuclei degenerating.  $\times 1216$ .

## PLATE 12

- Fig. A. Section of a hemlock leaf, showing aecial primordium and pycnia.
- Fig. B. Section through mature aecium, stained with safranin and gentian violet to show gelatinizing intercalary cells and extent of gelatin (dark band).
- Fig. C. Mature pycnium in section of hemlock leaf.
- Fig. D. Section of diseased hemlock leaf showing position of aecia and dark bands, indicating gelatinization, in the aecia.
- Fig. E. Section of hemlock leaf, showing considerable hydrolysis of starch in the wing containing an aecium, and much less hydrolysis in less infected wing.
- Fig. F. Section of hydrangea leaf, showing row of teliospores in upper epidermis.
- Fig. G. Section of hydrangea leaf (lower surface up), showing mature uredinium.



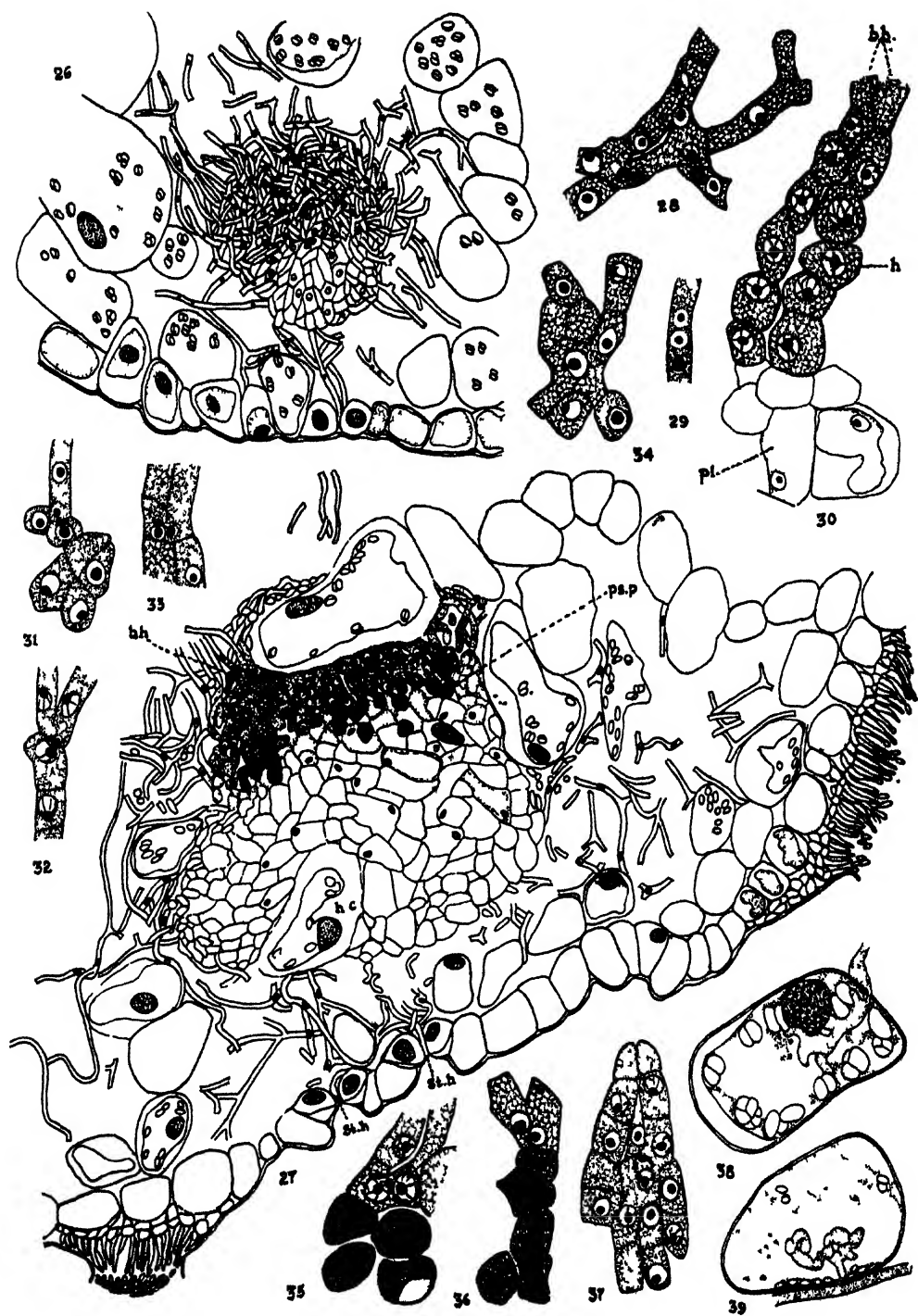
# PLATE 5







# PLATE 6

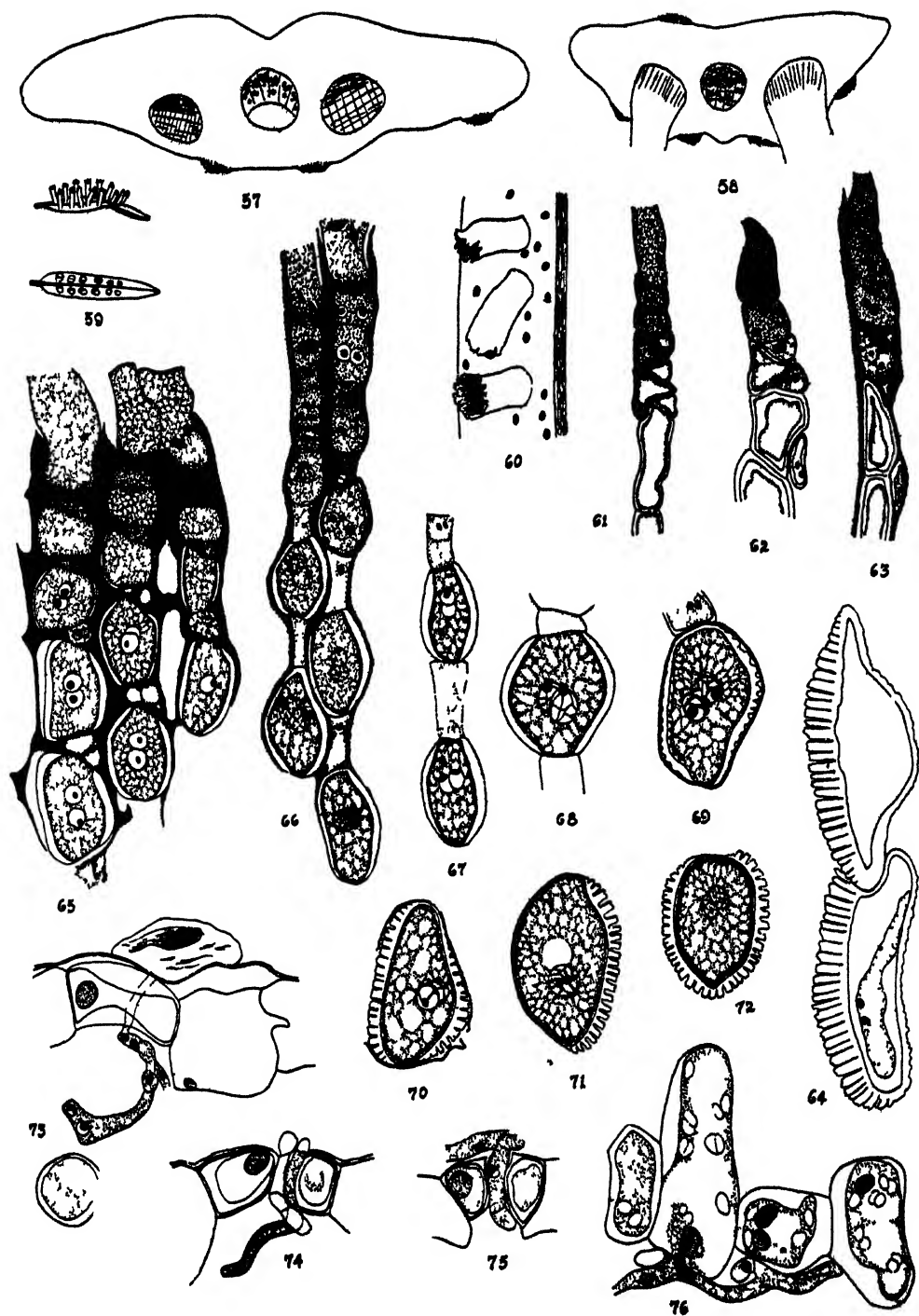






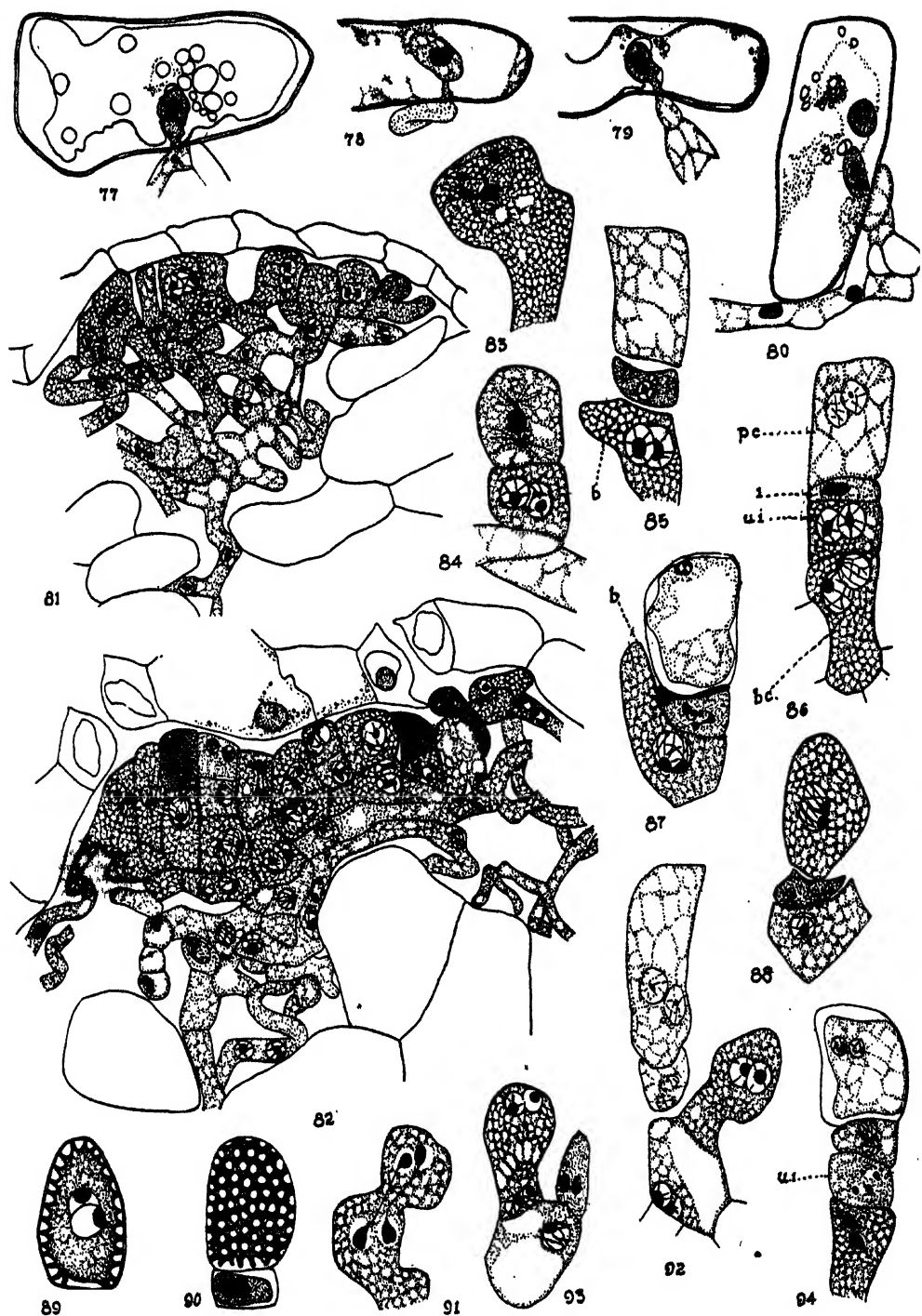


# PLATE 8





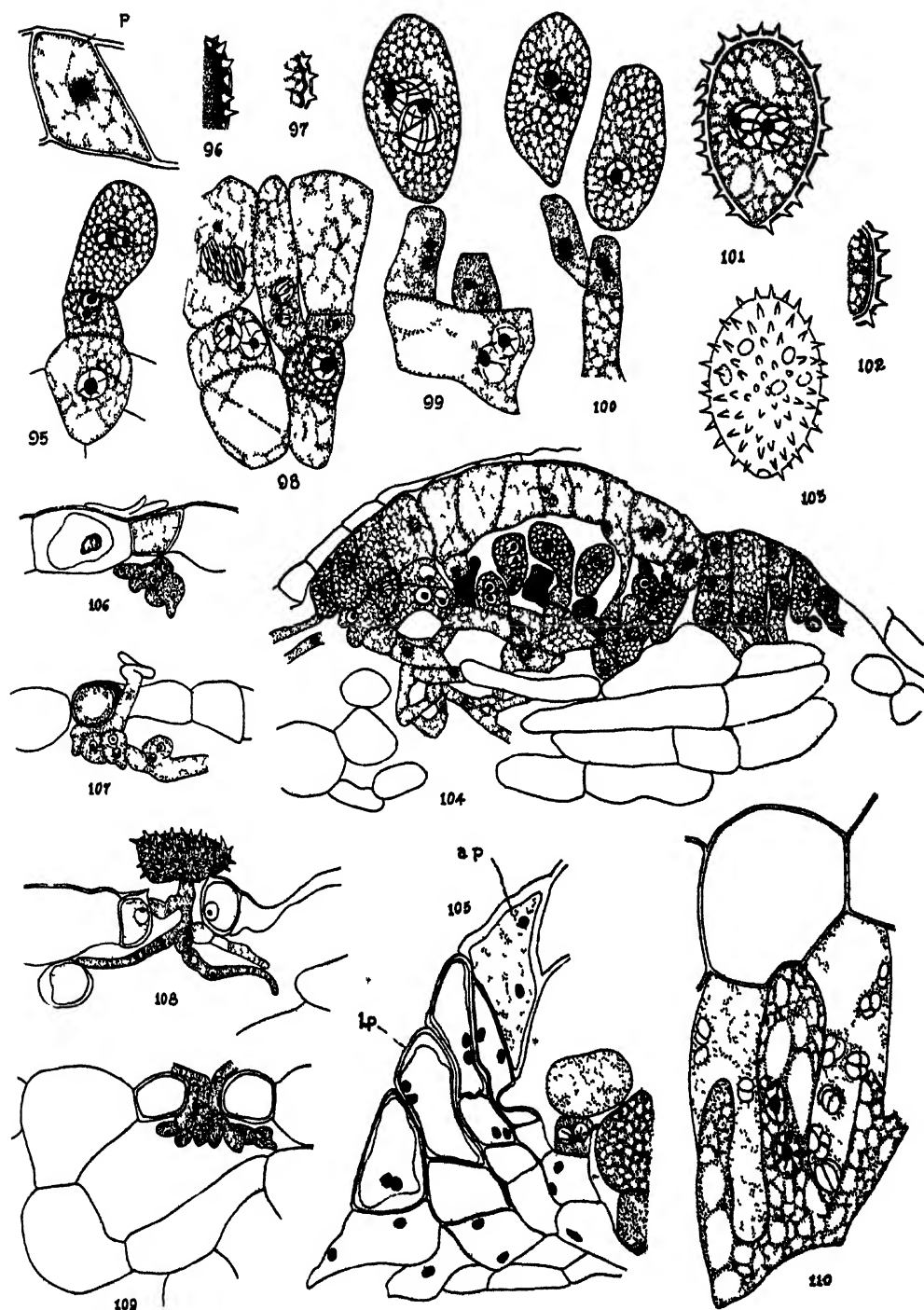
# PLATE 9







# PLATE 10





# PLATE 11

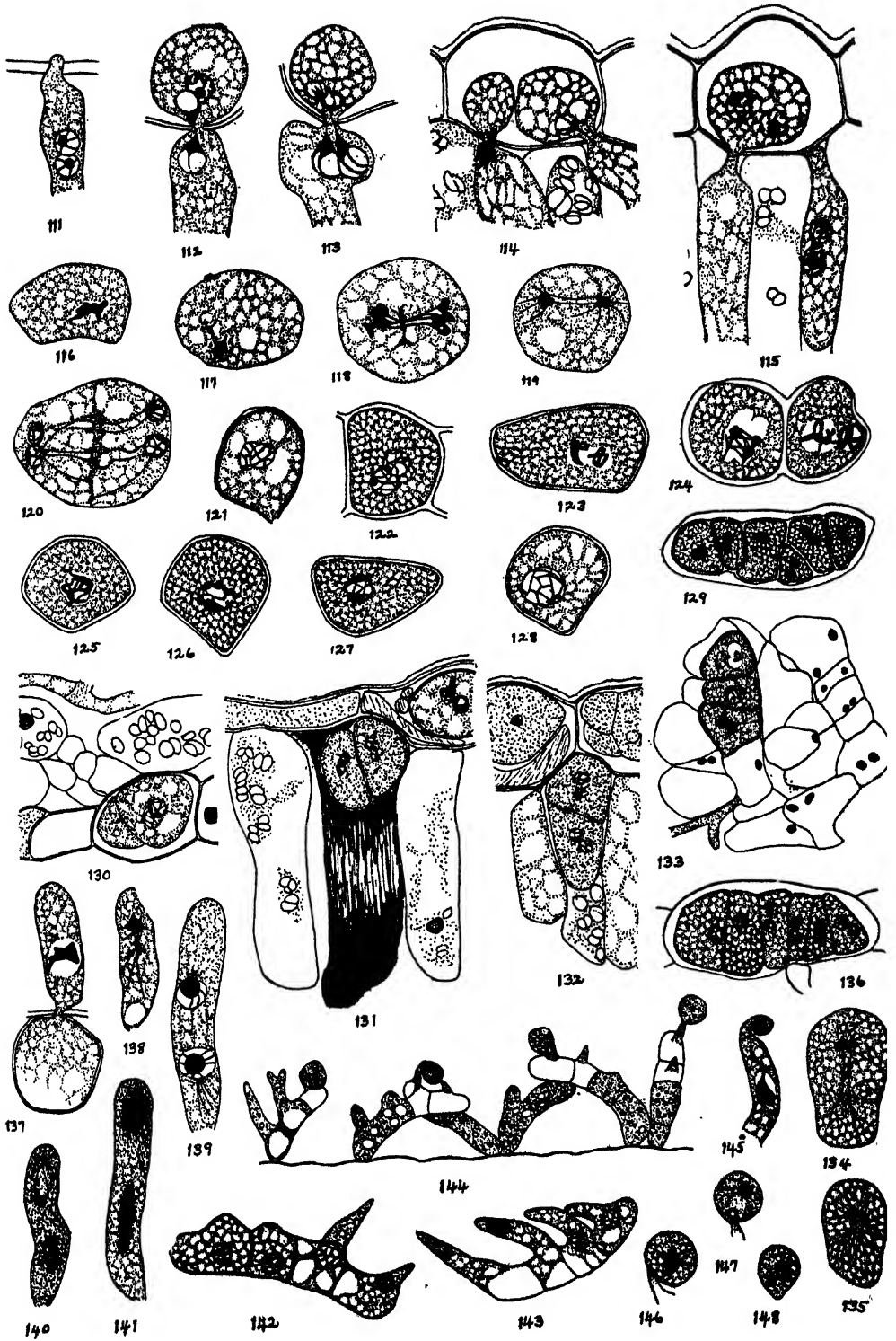
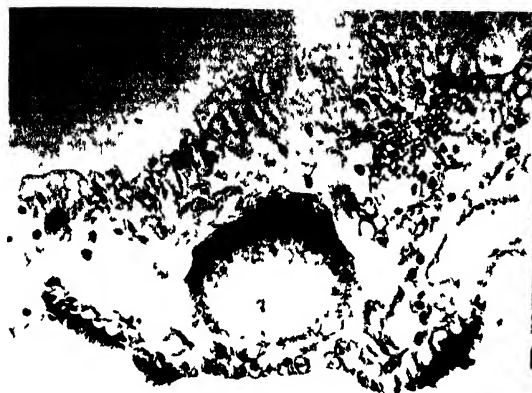




PLATE 12



A



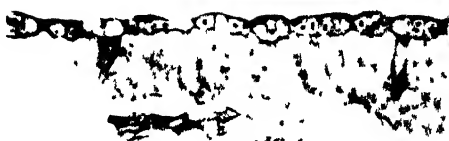
B



D



E



F





# AN F<sub>2</sub> COLCHICINE-INDUCED TETRAPLOID CABBAGE AND SOME COMPARISONS WITH ITS DIPLOID PROGENITOR

BY EARL H. NEWCOMER

## PLATES 13-16

The importance of colchicine to practical as well as theoretical genetics is unquestioned. Despite the sometimes frantic claims made for it upon its recent introduction, it has effectively met a long felt need of cytologists for a method whereby polyploidy could be induced in many plants. At present it is being widely and successfully used and it is too early to attempt to evaluate its significance. Mention of several of the more important achievements secured through its use, indicating its practical and theoretical value to the cytologist and geneticist, should include such things as the rendering fertile of sterile hybrids through amphidiploidy, crossing hitherto uncrossable species through ploidy of one parent, production of triploids and other polyploids (3), the production of polysomics and the achievement of homozygosity in a single generation by treating haploids (4). Much of the literature has been recently reviewed by Dermen (2) and some of the physiological, morphological, and practical implications of the use of colchicine have been briefly reviewed by Nebel (3) and Barr and Newcomer (1, 5).

That increase in size which is usually but not always concomitant with polyploidy will, perhaps, not constitute the most important contribution of colchicine to the plant breeder, is suggested by recent studies on the physiological and nutritional aspects of polyploidy (1).

## MATERIALS AND METHODS

Cabbage seedlings, variety Ferry's Hollander, were grown in flats in the greenhouse and while vigorously growing, were treated by pipetting the apical bud with a 0.2% solution of colchicine in the emulsion originated by Warmke and Blakeslee (6). This formula is superior to any others we have used and is as follows:

Stearic acid.....	3.00 grams
Morpholine.....	1.06 cc.
Tap water.....	40.00 cc.
Lanolin.....	16.00 grams

Add water to stearic acid and morpholine and heat mixture until the stearic acid is melted. Stir to a creamy soap solution. Add lanolin and continue heating until the lanolin is melted and the mixture is just below the boiling point. Stir to an emulsion and continue stirring intermittently until the emulsion is cooled to room temperature.

The emulsion must be diluted for spraying. Dilute by adding four parts of water to one of emulsion. The colchicine is then added to the desired concentration. This emulsion is very stable if kept in a cool place.



Applications of this mixture were made daily for three to six days. Upon the cessation of growth and the appearance of hypertrophy the plants were placed in the field where they matured with grossly abnormal, dichotomously branched stems and small, thickened leaves. In the fall, these plants were taken from the field, stored in a cold room until February when they were transferred to the greenhouse and forced for seed. In the cabbage, which is a biennial, the seeds thus obtained can be planted immediately and in this way two generations of progeny were grown in two years.

#### OBSERVATIONS

##### 1. General morphological comparisons

	Diploid	Tetraploid
Flower petals.....	8 mm. x 22 mm.	10 mm. x 24 mm.
Pollen.....	24 $\mu$ x 30 $\mu$	34 $\mu$ x 40 $\mu$
Stomata.....	18 $\mu$ x 21 $\mu$	26 $\mu$ x 36 $\mu$
Plastids.....	ca 7 $\mu$	ca 7 $\mu$
Seeds.....	see fig. 21	see fig. 22

The flowers of the tetraploid, in addition to being conspicuously larger (cf. figs. 1 and 2), show other differences from the corresponding diploid. The sepals and petals are more divergent, the latter with obovate blades which taper toward the base, whereas in the diploid, the blades are nearly elliptical with crisped margins. The style of the tetraploid is distinctly curved at the tip, the anthers more strongly contorted and the corolla is more definitely salver-form.

Similarly, in all the other morphological comparisons made with the exception of the plastids, the tetraploid shows an advantage in size, most marked in the stomata (cf. figs. 3, 4), pollen grains (cf. figs. 5, 6 and 9, 10) and in general phenotypic appearance. There is no difficulty in distinguishing between the two in the field. The tetraploids are later in maturing (cf. figs. 17, 18), and the leaves are larger and thicker. This difference in thickness and stiffness of the leaves is apparent to the touch.

Seeds of the tetraploid average larger, although some of the larger diploid seeds equalled in size those of the smaller tetraploid seeds (cf. figs. 21, 22).

A cross section through the cotyledons (figs. 11, 12) of five-day-old seedlings shows that the increased thickness of the tetraploid cotyledons is due to an increase in cell size and not to an increase of number of cells. In numbers of cells they seem to be approximately equal.

Observations on the comparative behavior of the chromosomes during meiosis were only preliminary to a more detailed study to be made later. There were evidences of multivalent associations (fig. 13) with quadrivalents the most common. Disjunction appeared to be normal and functional gametes formed. Fertility of greenhouse-grown plants was high, but seldom exceeded 70% of complete fertility.

Crosses between the tetraploid and diploid gave seed only when 2n pollen was used, but to date none of the 3n seeds have produced viable seedlings.

## 2. Physiological comparisons

As to the internal, physiological consequences of the new genetic regime established by polyploidy, we have only a meager and superficial knowledge from which no generalizations are possible at the present time. Recent comparative studies of these cabbages (1), in such things as reducing sugars, acid hydrolyzable substances, soluble nitrogen, residual nitrogen and vitamin C revealed that the tetraploid cabbage contained higher concentrations of all substances, save soluble nitrogen, when tested on a fresh weight basis. Vitamin C content of the lower green leaves of the tetraploid was found to be slightly over four times that of the corresponding diploids. Increases in the other analyzed substances, save soluble nitrogen, averaged between 25-50% in the autotetraploid. The possibilities of this aspect of polyploidy in a plant breeding program from the point of view of general nutrition, drug production, etc., seem to be as great as they are obvious.

### SUMMARY

The colchine-induced autotetraploid cabbage of this study was larger in every morphological comparison made, with the exception of chloroplasts, than the corresponding diploid progenitor. In addition to quantitative morphological changes, flowers show certain qualitative distinctions. Difference in thickness of the cotyledons and also presumably the leaves, was not due to increase in cell number but to increase in cell size. With the exception of primary multivalent pairing, chromosome behavior was normal, producing functional gametes and about 70% of complete fertility.

Physiological studies, in which the 4n and 2n cabbages were analyzed for reducing sugars, total sugars, acid hydrolyzable substances, soluble nitrogen, residual nitrogen and vitamin C revealed that, with the exception of soluble nitrogen, the tetraploid contained from 25% to 50% more of these substances. The lower leaves of the tetraploid contained four times as much vitamin C as the corresponding leaves of the diploid.

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## EXPLANATION OF PLATES

All figures are paired. The odd numbered figures on left side of plates are tetraploid; those on the right side and even numbered are diploid.

## PLATE 13

- Fig. 1. Flower of tetraploid plant.
- Fig. 2. Flower of diploid plant.
- Fig. 3. Stomata, guard cells and lower epidermal cells of tetraploid,  $\times 675$ .
- Fig. 4. Stomata, guard cells and lower epidermal cells of diploid,  $\times 675$ .
- Fig. 5. Pollen grains of tetraploid,  $\times 150$ .
- Fig. 6. Pollen grains of diploid,  $\times 150$ .

## PLATE 14

- Fig. 7. Chloroplasts of tetraploid,  $\times 675$ .
- Fig. 8. Chloroplasts of diploid,  $\times 675$ .
- Fig. 9. Pollen grains of tetraploid,  $\times 675$ .
- Fig. 10. Pollen grains of diploid,  $\times 675$ .

## PLATE 15

- Fig. 11. Cross section through 5-day-old cotyledon of tetraploid,  $\times 150$ .
- Fig. 12. Cross section through 5-day-old cotyledon of diploid,  $\times 150$ .
- Fig. 13. Chromosomes in first meiotic metaphase of tetraploid,  $\times 675$ .
- Fig. 14. Chromosomes in late diakinesis of diploid,  $\times 675$ .
- Fig. 15. Chromosomes in second metaphase of tetraploid,  $\times 675$ .
- Fig. 16. Chromosomes in second metaphase of diploid,  $\times 675$ .

## PLATE 16

- Fig. 17. Field grown tetraploid cabbage.
- Fig. 18. Field grown diploid cabbage of same age as plant in fig. 17.
- Figs. 19, 20. Two rows of tetraploid and diploid plants in the field, respectively.
- Fig. 21. Seeds of tetraploid.
- Fig. 22. Seeds of diploid.

PLATE 13

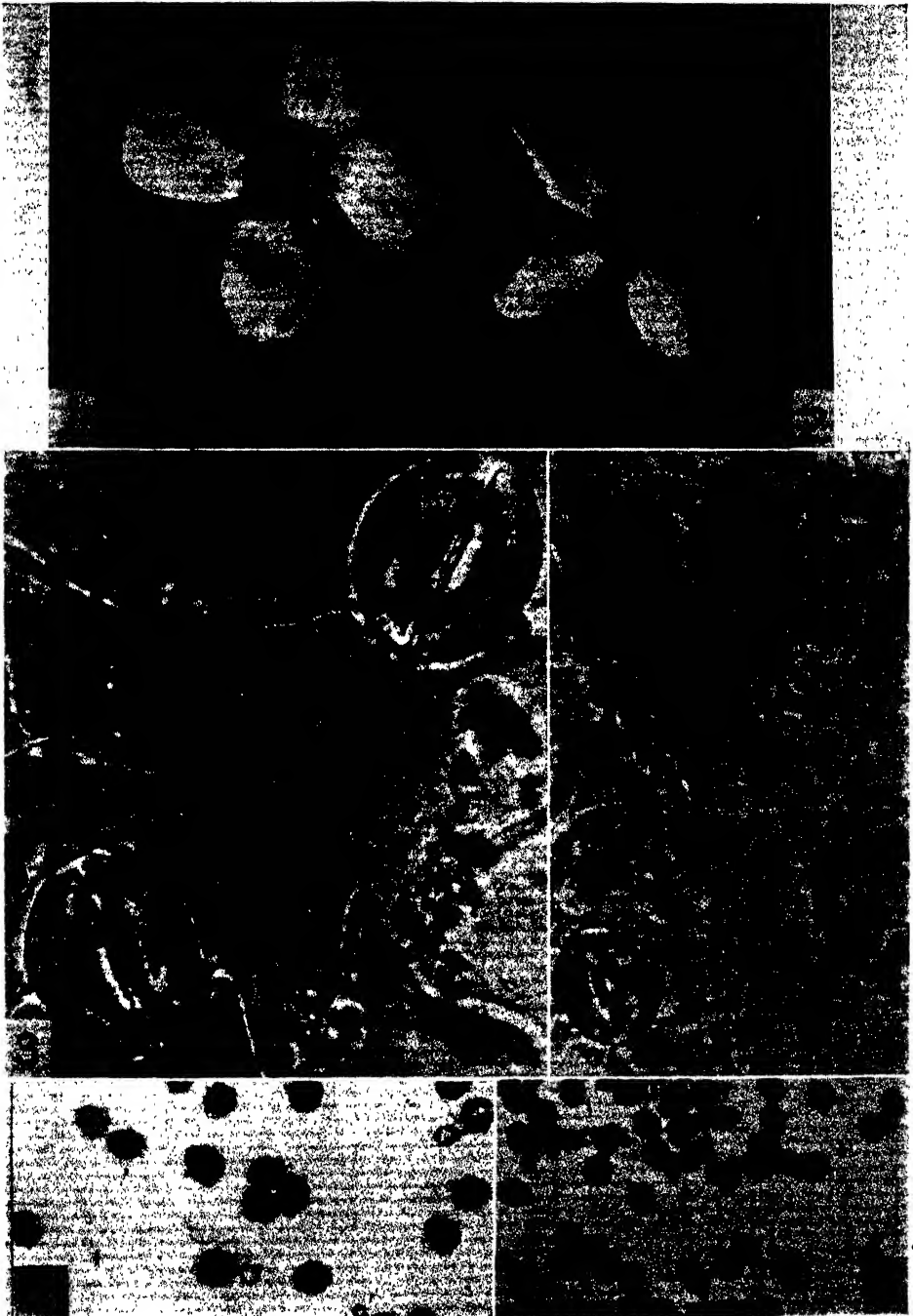




PLATE 14

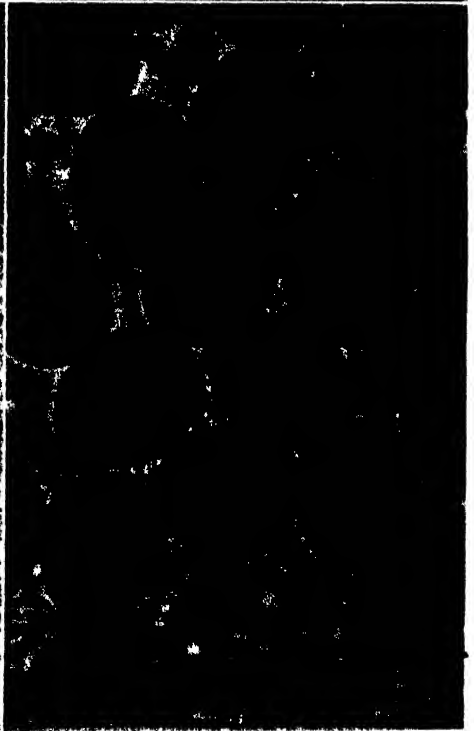
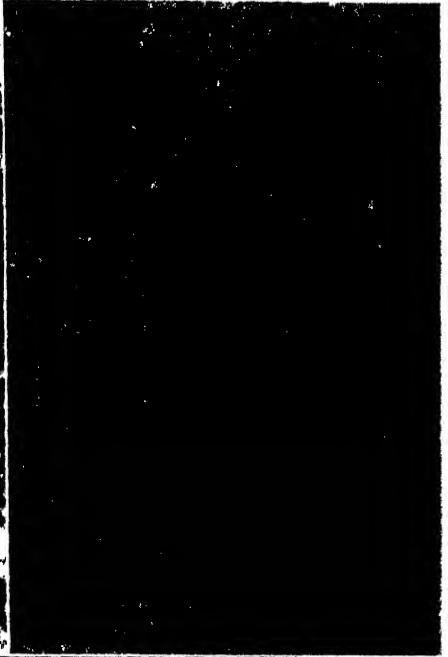




PLATE 15

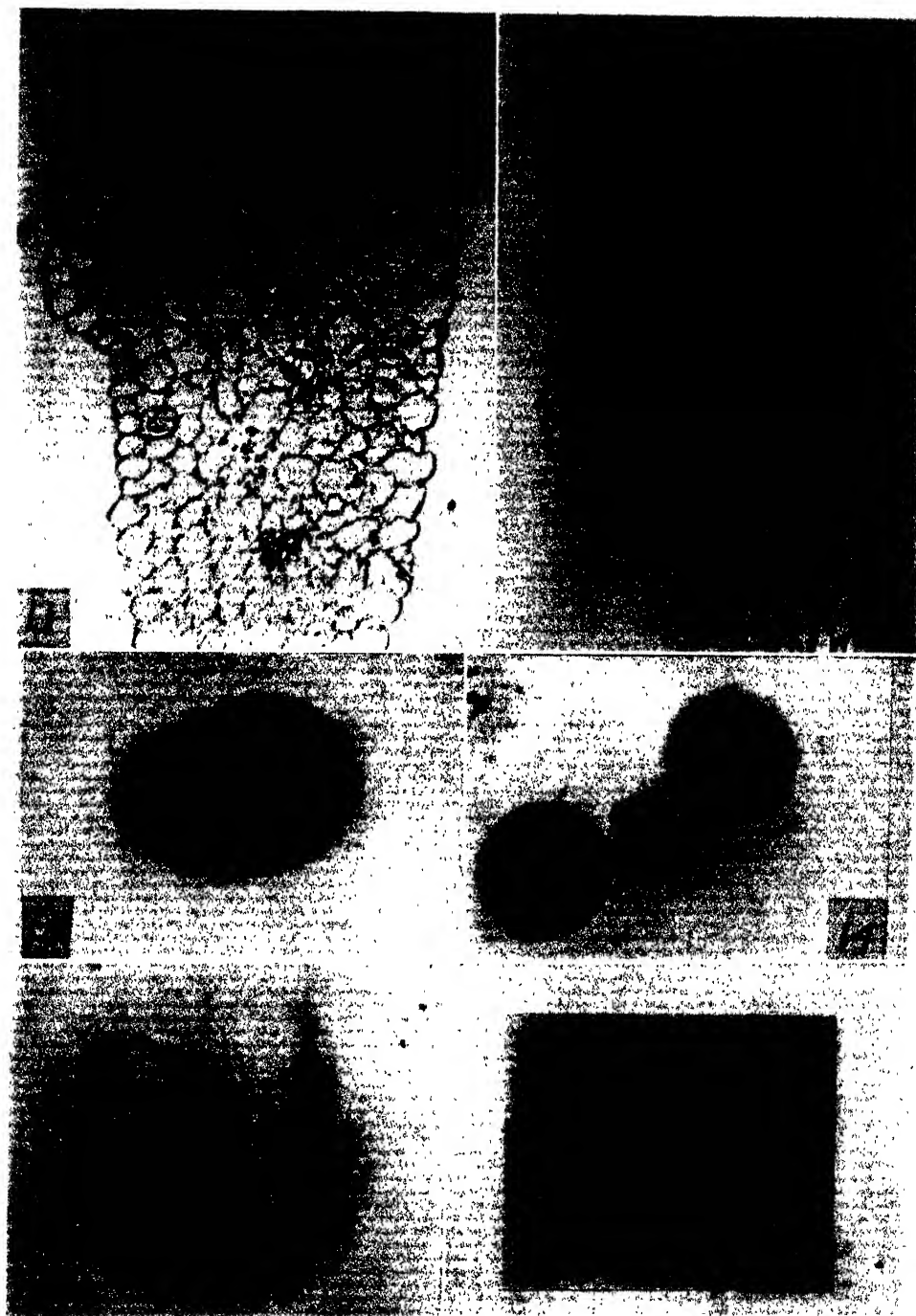
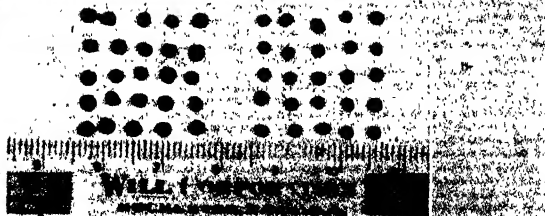
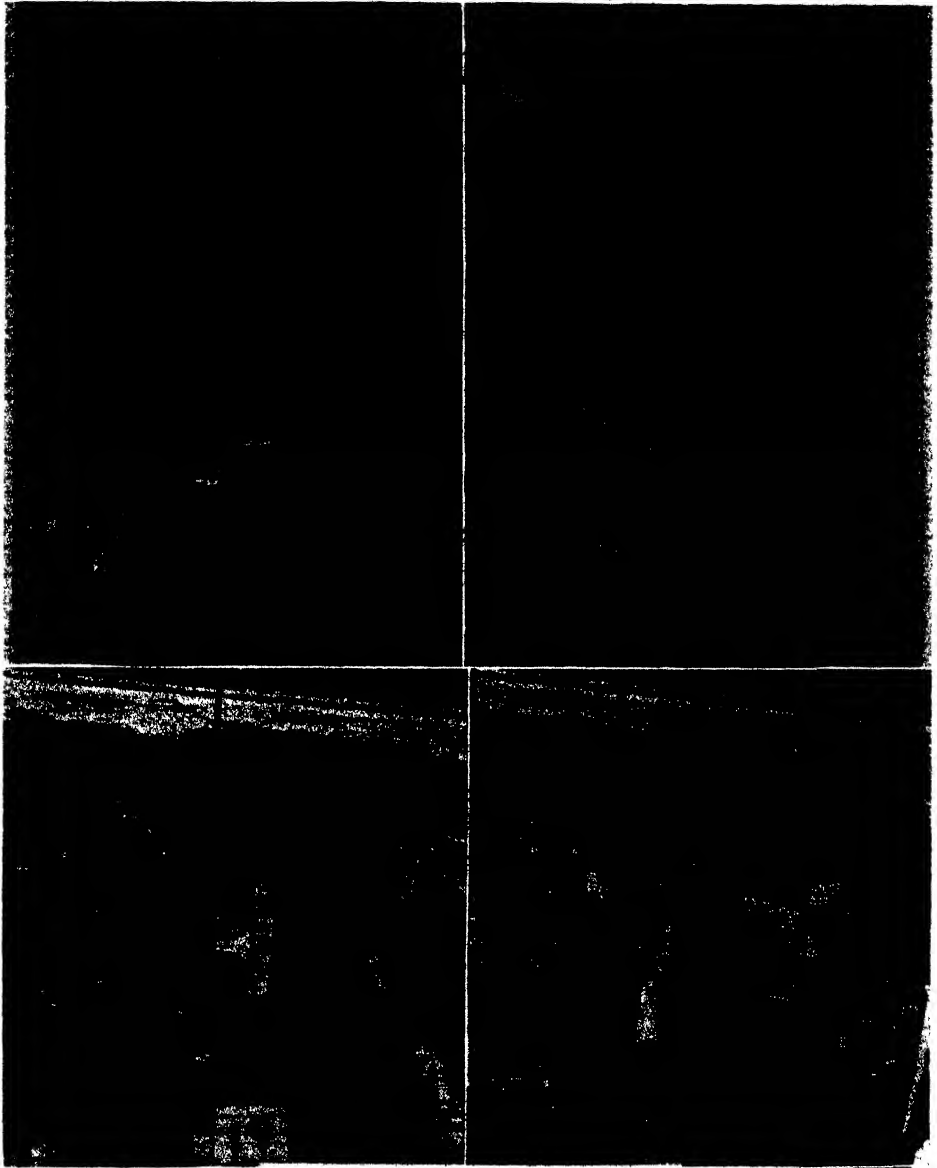






PLATE 16





# STUDIES OF NATURAL POPULATIONS OF *CUTHBERTIA GRAMINEA* IN THE CAROLINAS

By NORMAN H. GILES, JR.

## TWO TEXT FIGURES

Cytotaxonomic and cytogenetic studies of natural plant populations are essential in any attempt to evaluate the relative importance of genetic mechanisms responsible for variation and for evolution, especially at and below the species level. One of the most widespread of these mechanisms in the flowering plants is polyploidy—both the auto—and allotypes. Consequently, a proper evaluation of its role in speciation is of considerable importance (cf. Stebbins, 1940). A study of polyploidy in natural populations is of further interest, since such an investigation often makes possible, when correlated with geographical and geological data, a rather precise interpretation of the evolutionary history of a given species or group of related species (Manton, 1934; Stebbins, 1942).

The present discussion is concerned with autopolyploidy within the taxonomic species, *Cuthbertia graminea* Small. Furthermore, it is restricted primarily to a consideration of the extent and significance of the geographical ranges of the various cytological forms of the species found in the Carolinas. The more general conclusions have already been presented (Giles, 1942). It has been shown as a result of extensive collections of living material for cytological examination that *C. graminea* occurs in nature in two principal forms, a diploid and an autotetraploid. A comparison of these two forms shows that the tetraploids differ from the diploids in several respects: (a) they are larger, more vigorous plants; (b) they are more variable cytologically; (c) they exhibit a greater ecological amplitude; (d) their geographical range is much greater, and further, the ranges of the two forms (in so far as the collections up to that time indicated) are distinct. More collections have been made since the paper cited was published, and it is now clear that the two ranges are indeed strikingly distinct, and that the diploids are confined to the Carolinas. Furthermore, the range of the diploids has been delimited with considerable exactness.

## DATA ON COLLECTIONS

With the assistance of several cooperative collectors it has been possible to secure living specimens of *C. graminea* from many different stations in the Southeast. An extensive collection was possible largely because of the relative ease with which the plants can be obtained during trips by automobile. The species is almost entirely confined to a characteristic vegetation-habitat complex: the wiregrass, turkey-oak, long-leaf pine association of xeric sandy areas on the Coastal Plain (cf. Wells and Shunk, 1931). These areas can be easily recognized as one travels through the region, and stops can be made at frequent intervals to collect living plants for subsequent examination in the laboratory. Many of the collections were grown at the Arnold Arboretum of Harvard University and at the Marsh Botanical Gardens of Yale University.

TABLE 1

*Data on collections of Cuthbertia graminea in the Carolinas*

Under locality, the distance and direction of the collecting station from a nearby point of reference are given; numbers refer to federal (U.S.) and state highways. Abbreviations of collectors' names are as follows: R = Mr. H. A. Rankin; K = Dr. Thomas Kerr; S = Dr. C. P. Swanson; O = Dr. H. J. Oosting; T = Mr. F. G. Tarbox, Jr.; B = Mr. R. K. Godfrey; G = the writer and his wife. For further explanation see text.

COLLECTION NAME	NO. OF PLANTS	CHROM. NO.	LOCALITY	COLLECTOR
Rankin	3	2x	Lillington, N. C., 7 mi. S U. S. 15A	R
Harnett	3	2x	Spout Springs, N. C., 2 mi. SE State 87	K, S, G
Fort Bragg	7	2x	Fort Bragg, N. C., State 87	K, G
Moore	1	2x	Moore County Line, N. C., S State 211	K, G
Aberdeen	2	2x	Aberdeen, N. C., 3 mi. S U. S. 15	K, G
Sanatorium	2	2x	Sanatorium, N. C., 2 mi. SE State 211	K, G
Raeford	2	2x	Raeford, N. C., 2 mi. NE U. S. 15A	K, G
Hoke	3	2x <sup>a</sup>	Hoke County Line, N. C., N U. S. 15A	K, G
Hoffman	1	2x	Hoffman, N. C., 3 mi. NE U. S. 1	K
Marston	1	2x	Marston, N. C., 3 mi. SW U. S. 1	K
Scotland	1	2x	Laurinburg, N. C., 10 mi. N U. S. 15A	K, G
Robeson	2	2x	Rennert, N. C., pocosin 1 mi. E	K, G
Hamlet	4	2x	Hamlet, N. C., 2 mi. E U. S. 74	G
Old Hundred	3	2x	Old Hundred, N. C., U. S. 74	G
Cash	4	2x	Cash, S. C., U. S. 52	G
Bear Creek	6	2x	Chesterfield, S. C., 8 mi. S State 102	G
Sandhills	3	2x	Patrick, S. C., 4 mi. SE State 102	G
Coker	1	2x	Hartsville, S. C., $\frac{1}{2}$ mi. N U. S. 15	G
McBee	6	2x	McBee, S. C., 5 mi. SE State 151	G
Pearce	3	4x	Fayetteville, N. C. (near)	R
Vander	1	4x	Vander, N. C., State 24	K, G
Cumberland	4	4x	Fayetteville, N. C., 5 mi. E State 24	K, S, G
Fayetteville	3	4x	Fayetteville, N. C., 5 mi. S	R
Rex	3	4x	Rex, N. C., pocosin rim near	K
St. Paul's	2	4x	St. Paul's, N. C., 4 mi. E State 20	K
Page's Lake	3	4x	Bladen County, N. C., NW corner, State 20	K
Kenan	8	4x	Kenansville, N. C., 8 mi. S State 11	K, S
Burgaw	5	4x	Burgaw, N. C., by North East Cape Fear River, State 53	K, S
White Lake	3	4x	White Lake, N. C.	R
Bladen	1	4x	Black River at Beatty's Bridge, N. C.	R
Warwich Bay	2	4x	Lumberton, N. C., 10 mi. SE	K
New Hanover	3	4x	Carolina Beach, N. C., 3 mi. N	O
Carolina Beach	2	4x	Carolina Beach, N. C. $\frac{1}{2}$ mi. N	K, S
Brunswick	1	4x	Southport, N. C., 4 mi. W	K, G
Laurinburg	1	4x	Laurinburg, N. C., 5 mi. SW U. S. 15	G
Society Hill	1	4x	Society Hill, S. C., 1 mi. SW U. S. 15	G
Segars	7	4x	Segars, S. C., 2 mi. W State 151	G
Chesterfield	2	4x	McBee, S. C., $1\frac{1}{2}$ mi. SW U. S. 1	G
Lynches	4	4x	McBee, S. C., 3 mi. SW U. S. 1	G
Bethune	12	4x	Bethune, S. C., 2 mi. SW U. S. 1	G
Cassatt	2	4x	Cassatt, S. C., $5\frac{1}{2}$ mi. SW U. S. 1	G

TABLE 1—*Concluded.*

COLLECTION NAME	NO. OF PLANTS	CHROM. NO.	LOCALITY	COLLECTOR
Kershaw	2	4x	Camden, S. C., 5 mi. NE U. S. 1	G
Camden	2	4x	Camden, S. C., 4 mi. NE U. S. 1	G
Blaney	3	4x	Blaney, S. C., 3 mi. NE U. S. 1	G
Columbia	1	4x	Columbia, S. C., 2 mi. NE U. S. 1	G
Congaree	6	4x	Columbia, S. C., 5 mi. W U. S. 1	G
Lexington	4	4x	Lexington, S. C., 5 mi. W U. S. 1	G
U. S. 1	3	4x	Monetta, S. C., 2 mi. S U. S. 1	G
Monetta	3	4x	Monetta, S. C., 3 mi. S U. S. 1	G
Edmund	1	4x	Edmund, S. C., 3 mi. N State 215	G
Aiken	9	4x <sup>b</sup>	Aiken, S. C., 5 mi. NE U. S. 1	G
South Fork	2	4x	Aiken, S. C., 8 mi. E State 215	G
Tarbox	1	4x <sup>c</sup>	Brookgreen, S. C.	T
Godfrey	1	4x	Georgetown, S. C., 10 mi. N U. S. 17	B
Georgetown	3	4x	Georgetown, S. C.	B

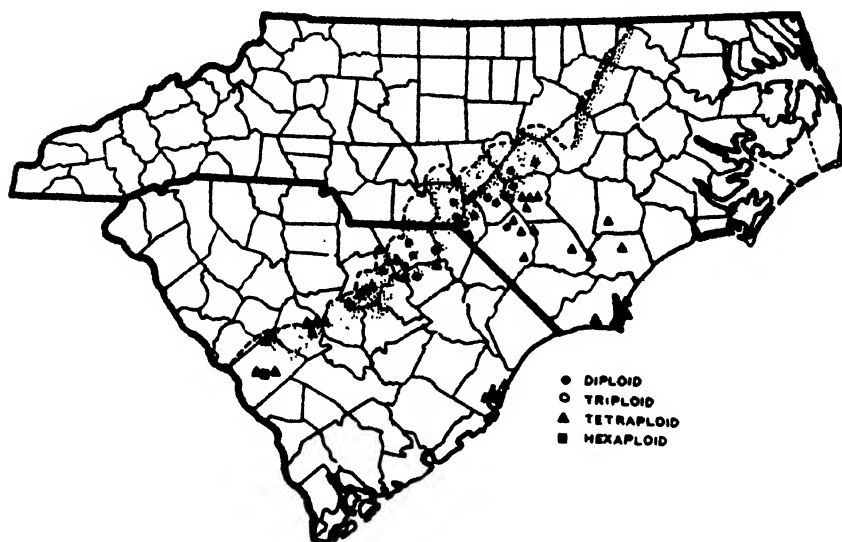
<sup>a</sup> 1 = 3x.<sup>b</sup> 1 = 6x; 1 = 4x + 1.<sup>c</sup> Data from Anderson and Sax (1936).

FIGURE 1. Distribution of the cytological forms of *Cuthbertia graminea* in the Carolinas. The approximate position of the Fall Line is shown by the broken line, and the approximate limits of the surficial Cretaceous sediments by stippling.

The data on all collections which have been made in the Carolinas are presented in table 1. A collection name has been assigned to all the plants from one station. The number of plants at each station for which successful cytological determinations were obtained is then given, followed by the chromosome numbers of the plants. Next the location of the collection is given in some detail,

special reference being made to state and national highways along which most of the collections were made. The last column indicates by letter the name of the collector. The collections are arranged with diploid stations first, in approximate geographical order from north to south, followed by the tetraploid stations arranged in the same way. In all there are 55 stations in the Carolinas, 19 being diploid localities and 36 tetraploid localities. A total of 169 plants has been examined cytologically. The locations of the stations are indicated on a county outline map of the Carolinas in figure 1.

#### DISCUSSION

It is at once clear from the collection data and from the ranges indicated on the map that the two cytological forms occupy distinct areas. In no instance have they yet been found growing together at the same station, although several of the stations of the two types are only a few miles apart. There is, however, some evidence that crossing of the two forms occurs naturally. A single triploid individual was found at the Hoke station, which is on the periphery of the diploid range where it comes in contact with the range of the tetraploids. This one example is not sufficient to indicate that extensive hybridization of the two types occurs, since relatively few plants from the zone of contact of the two populations have been examined cytologically. Even if crossing does occur in certain areas with considerable frequency, it is of course clear that the two types will remain effectively isolated genetically, since the high degree of sterility of the hybrid triploids (which have been produced and tested experimentally) would almost entirely preclude any exchange of genes between the two populations.

It is clear that a form such as an autotriploid with an odd number of chromosome sets could not become an established element in populations of a sexually reproducing species. However, higher autopolyploids with an even number of chromosome sets do possess the possibility of fairly regular sexual reproduction. Autohexaploids could arise by somatic chromosome doubling in triploids resulting from hybridization of diploids and autotetraploids. Such hexaploids would then be expected to occur where the ranges of the two other forms meet. An example of this sort is found in *Sedum pulchellum* Michx. (Baldwin, 1943). Hexaploids might also arise occasionally in a pure tetraploid population as a result of the union of a tetraploid and a diploid gamete. Such individuals would be rare, and the chances of hexaploids becoming established in a population in this manner would appear to be very slight. The single hexaploid found in this study (at the Aiken station) clearly did not arise from hybridization, since the locality where it was found is considerably beyond the limits of the diploid range. It must be a sporadic case of the sort just mentioned. There is no present evidence that *autohexaploids* constitute a real element in the natural populations of *C. graminea*. If they existed in any number it would appear that they should have been found in the zone where the diploid and tetraploid forms meet, and such has not been the case. It should be pointed out that the hexaploid individual reported previously from central Florida has been found to be part of a hexaploid population and originated in an entirely different manner genetically from the Aiken autohexaploid (Giles, unpublished).

Certain important characteristics of the range of the diploids may now be pointed out. It is evident that this form occupies a much smaller area than do the tetraploids, especially when it is recalled that the range of the latter extends well into Florida. Further, the diploids are almost entirely confined to the Sandhills adjacent to the Fall Line, from the vicinity of Lillington, N. C., to McBee, S. C., whereas the tetraploids occur on the Coastal Plain terraces as well. As was pointed out previously (Giles, op. cit), there is a clear correlation between the geology of the region and the geographical and cytogenetical data. The diploids, which are known from genetic evidence to be the ancestral type, occupy an area which is much older geologically than that in which the majority of the tetraploids occur. The Sandhill area of the Carolinas, the northern part of which was formerly included in the Lafayette formation (Stephenson, 1912) is now considered to be largely Upper Cretaceous and subordinately Paleocene in age (Cooke, 1936; Stephenson, 1940). It is probable that this region has not been under the sea since early Tertiary at the latest. The region between the surficial Cretaceous sediments and the present coast line is much younger in age; most of the coastal terraces, which occupy a considerable fraction of this area, being of Pleistocene origin. The diploids must represent then the ancestral population and its descendants, which now occupy entirely or in part their original range in a region geologically old, whereas the derived and more vigorous autotetraploids have been the effective colonizers of extensive new areas as they became available for occupation by land plants.

In order to show quite clearly the extent of the correlation between the range of the diploids and the geology of the Carolinas, figure 2 is presented. On this map the approximate limits of the surficial Cretaceous sediments are indicated by stippling, and the extent of the diploid area is shown by oblique lines. It can be seen that the area which the diploids occupy in southern North Carolina and in northern South Carolina as far south as McBee parallels quite closely (with the exception of the Robeson station) the limits of the Cretaceous-Paleocene sediments, and it was at first thought that this form would occur throughout the Cretaceous area. South of McBee, however, tetraploids are found in the Fall Line Sandhills. As far as is known at present there are no fundamental geological differences which distinguish these two Sandhill regions. About the only differences seem to be topographic and edaphic ones, since the topography and soil zones are more continuous in the diploid area, less cut to pieces by transverse streams, and wider, in general, than in the area to the northeast or southwest (Eargle, 1942). One major question then remains: Did the diploids once occupy all the Fall Line Sandhill region and perhaps a considerable portion of the adjacent regions as well (having been displaced sometimes in the past from a part of their range by the tetraploids), or does their present range represent the entire extent to which they spread in the past, the tetraploids having originated somewhere along the present zone of contact and then having colonized the remainder of the Coastal Plain? It does not seem possible to decide between these two alternatives as yet. However, a method of attacking the problem does suggest itself. Since the present limits of the diploid area are now known with considerable exactness, it would seem that further population studies in the



region where the two types approach one another might provide valuable information as to the present relation between them. More information is desirable concerning conditions on the periphery of the diploid range, especially at two points: the outlying Robeson station and adjacent Hoke and Scotland counties in North Carolina; and the McBee-Hartsville region (Segars, Chesterfield, Coker, and McBee stations) at the southern limit of the diploid range in South Carolina. Is there any evidence that the tetraploids are replacing the diploids in localized areas? How do the reproductive potentials of the two types compare? Ecological studies, perhaps over a period of years, might indicate actual shifts in the relations of the populations. Such information, besides making possible a more exact interpretation of the history of the diploid form, should be of quite

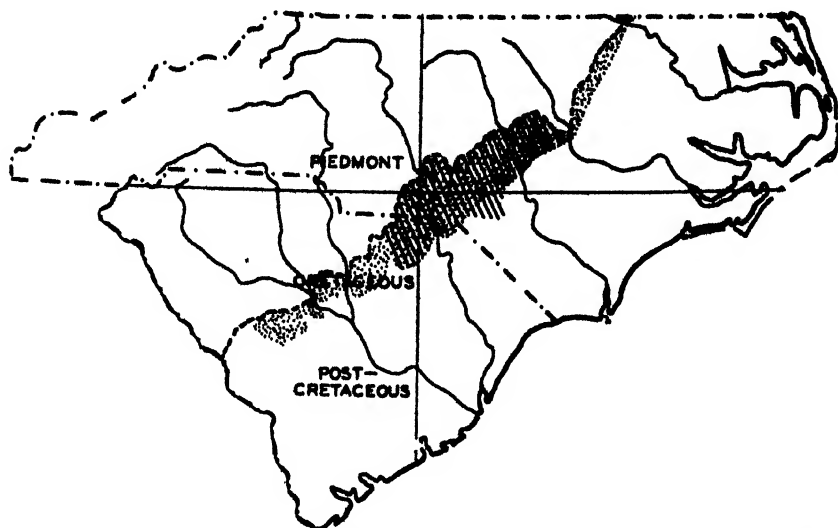


FIGURE 2. The diploid area of *Cuthbertia graminea*. The extent of this area is shown by oblique lines. Other symbols as in figure 1.

general interest, since it bears directly on the larger problems of how competition and selection operate in nature.

One more aspect of the present study should be mentioned. There is now botanical as well as geological evidence that the Fall Line Sandhill region is older than the rest of the Coastal Plain. If there is one relic plant population present in this region, may there not be others? Indeed, the recent extensive study of natural populations in the genus *Vaccinium* by Camp (1942) indicates that in this genus at least one of the diploid ancestral species found in the Southeast may be centered in the Sandhill region. The discovery of further examples of polyploid complexes and of relic populations may be anticipated in the southeastern Coastal Plain flora. It may well be that the combined evidence from such studies will facilitate an interpretation of the history of many of the species and perhaps of the general flora in this region with a much greater degree of certainty than has hitherto been possible.

## SUMMARY

Studies of natural populations of *Cuthbertia graminea* have demonstrated the existence of autopolyploidy within this taxonomic species, diploid, triploid, tetraploid, and hexaploid forms having been found. Extensive collections of living plants from throughout the southeastern Coastal Plain have shown that the diploids and tetraploids are the only abundant forms. Furthermore, it is now clear that the two forms occupy distinct regions. The diploids are confined to a relatively small area in the Fall Line Sandhills of the Carolinas, whereas the tetraploids occur in the remainder of the Coastal Plain, well into Florida. There is some evidence that occasional hybridization of the two types may occur in the zone where the two populations meet, a single triploid having been found at the Hoke station in North Carolina on the periphery of the diploid range. There is no evidence as yet that autohexaploids constitute a significant element in the species population, the single individual found at the Aiken station in South Carolina apparently representing an exceptional case which arose spontaneously in a tetraploid population.

A correlation of evidence from cytogenetics, geographical distribution, and geology indicates that the diploid form is largely confined to a small area which is geologically old (Cretaceous), whereas the derived tetraploid occupies a much larger area which is for the most part much younger in age (Pleistocene). The advent of autotetraploidy has been of major importance in the history of the *C. graminea* complex, since the demonstrably more vigorous tetraploids have been able to effect a great extension of the species range by colonizing new areas as they became available for occupation by land plants. Consequently, the tetraploids are now the dominant form in natural populations of this species, both numerically and in geographical range.

The relation between the two forms under the influence of natural selection is not yet clear, but there is some evidence from distribution that the tetraploid may have displaced the diploid from some of the latter's original range. The suggestion is made that further population studies in the zone where the two types meet might indicate whether such a displacement is taking place at present. Finally, it is pointed out that the Fall Line Sandhills in the Carolinas may well contain relic populations of other plant species, especially those in which polyploid complexes exist.

*Acknowledgments.* The writer would like to express his appreciation to the individuals listed in table 1 who have been of invaluable assistance in collecting living specimens. He is also indebted to the staff of the Department of Biology, Emory University, for facilities and materials used in the cytological examination of many of the collections.

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## MAGNOLIA CORDATA MICHAUX

By W. C. COKER

### PLATES 17-20 AND 6 TEXT FIGURES

Even as late as 1928 R. M. Harper spoke of *Magnolia cordata* as "this little-understood and somewhat mysterious species, or perhaps only a variety." Since that time a good deal has been found out about *M. cordata*, and the known distribution of the typical tree, or very slight variations from this tree, has been extended both eastward and westward from a small group of counties near Augusta, Georgia. It is now known to occur in the vicinity of Athens and several counties below this area, and more recently a very interesting extension has been discovered in central South Carolina. We are publishing herewith a map giving the present known range and including locations for all actual specimens we have been able to examine and also what we consider authentic records, though not yet supported by specimens we have seen. Before going into any detail as to these new discoveries and any additional knowledge brought out by them, we might first review the history of *Magnolia cordata*.

It was first named in the elder Michaux's Flora of North America in 1803. The very brief description in Latin (translation: leaves cordate, subtomentose beneath; flowers yellow) might as easily refer to what we are now calling the yellow-flowered variety of *M. acuminata* (*Tulipastrum acuminatum* var. *aureum* Ashe, 1917; later as *M. acuminata* var. *aurea* in 1931). Sargent (1891) says that the specimen in Michaux's herbarium in Paris is *M. acuminata*.

The younger Michaux in his North American Sylva (1857, first English edition, translated from first French edition of 1810) described *M. cordata* more fully and included an illustration in color. In this plate the flower is rather poorly done, in both form and color.

In neither of these works is it possible to tell whether *M. cordata* or *M. acuminata aurea* or both are involved. Fortunately however F. A. Michaux mentioned a particular station, "the plantation of Good-rest, twelve miles from Augusta, where, in my last journey to the United States, I noticed it along the sides of Horn Creek." This station is in Edgefield County, S. C., only about 20 miles from Spear's plantation where Berckmans rediscovered *cordata* on the other side of the river. It is only about 10 miles from where Ashe found it again in 1931 on the South Carolina side of the river near Augusta. It would seem permissible then for us to consider the tree found in this area typical, so far as we will ever know, of *M. cordata*. Up until the rediscovery by Mr. Berckmans, the tree was entirely unknown in the wild state. However, it had been introduced into cultivation in Europe by Michaux or by the Scotch collector John Fraser or probably by both (Loudon says it was introduced into England by John Lyon), and had later been brought back to America. Sargent (1889) says that when Asa Gray took charge of the Harvard Botanic Garden in 1842 he found there two already well grown trees of *M. cordata*. It was from one of these trees that

Sargent's description and Faxon's fine figure were made for the *Silva*. The younger Michaux had previously mentioned a cultivated "specimen in Mr. Pierce's arboretum, Chester county, Pennsylvania," and had noted a fact observed a number of times since, that the species blooms in both spring and fall.

In 1818 Nuttall states under *Magnolia cordata*: "Flowers yellow; appearing twice in the year in the garden of Mr. Landreth of Philadelphia. Leaves subcordate-oval, never truly cordate." There is a specimen from Nuttall's North American Herbarium in the New York Botanical Garden labelled *Magnolia cordata*, South Carolina (no other data). It is an excellent specimen, apparently typical for the species: twigs and leaves pubescent; flowers only 5 cm. long.

Elliott (1824) adds to the Michaux description: "Leaves of the calyx small." He evidently had seen the wild plant, for he continues: "Grows in the upper districts of Carolina and Georgia, more common around Augusta, than in any other part of the country with which I am acquainted."

Curtis (1860) evidently confuses the tree with *acuminata* var. *aurea*, as he gives it as occurring from the mountains of Ashe County, N. C., to Georgia, and his description is drawn entirely from Michaux.

Chapman (1897) gives the distribution as "Western parts of S. Carolina (*Michaux*), and Columbia County, Georgia, very rare." This is at present our only record from Columbia County. In all the editions of his *Flora*, Chapman includes both *cordata* and *acuminata*, but his distinctions do not hold well. In the last edition just cited he calls the flowers of both of them "yellow," which shows that he had in mind for *acuminata* the yellow-flowered southern mountain form now called var. *aurea*.

As far back as 1891, Sargent in his *Silva*, after discussing the cultivated form of *M. cordata*, says: "the exact counterpart of the cultivated plant is not known in a wild state. Forms approaching it in the shape and texture of the leaves, and in the size and color of the flowers, are occasionally found, however, on the Blue Ridge in Carolina and in central Alabama." As mentioned above, neither of the Michauxs made a distinction between the mountain and the sand hill forms in their treatment of *cordata*. Rehder (1940) also includes both *acuminata* and *cordata*, but he does not mention a southern yellow-flowered form of *acuminata*. For distribution of *cordata* he gives only Georgia.

Aside from the records of Nuttall, Elliott, and Chapman (and specimen from L. R. Gibbes from "South Carolina," in the New York Botanical Garden, noted below), none of which do I find mentioned by any writer since their time, *M. cordata* had remained, as Harper says, a mystery for at least 110 years. I may say here that while we cannot now consider the tree a mystery, we will still have to call it more or less of a puzzle, as will appear farther on.

The first new light that appeared in the knowledge of *M. cordata* came in 1913 when Mr. L. A. Berckmans of Augusta, Ga., found it at two places in Richmond County, Spear's Plantation and Goshen Plantation, a few miles south of that city. Dr. C. S. Sargent of the Arnold Arboretum (1914), in reporting this discovery, says: "The plants are growing in upland Oak and Pine woods, the largest of them being seven or eight feet tall. The plants begin to flower when not more

than three feet high, and in April of this year some of these shrubs bore forty or fifty flowers" (see also Sudworth, 1927). In a much earlier discussion of *M. cordata*, in which he had made an interesting comparison between the cultivated *cordata* and *M. acuminata*, Sargent (1886) first proposed the name *M. acuminata* var. *cordata*. This is the treatment he used in his *Silva* and the first edition of his tree *Manual*. The rediscovery of the feral tree caused him to change his mind and in the revised edition of his *Manual* he treats the tree as a species, but does not mention the yellow form of the mountains, which had previously so puzzled him. As far back as 1844 Loudon had considered *M. cordata* as cultivated in England as only a variety of *M. acuminata*.

In 1916 W. W. Ashe collected very typical specimens of the tree on the Spear place near Augusta, Ga., one of the stations where Berckmans had found it. These collections may now be seen in the herbaria of the University of North Carolina and New York Botanical Garden.

In 1917 Mr. J. S. Holmes, State Forester of North Carolina, found what we are now calling *cordata* in Anson Co., N. C., which adjoins the South Carolina line (Herb., University of N. C.).

In 1932 and 1933 Professor J. H. Miller of the University of Georgia discovered *cordata* in two places in Oconee County, Georgia. Since then Professor W. H. Duncan of the University of Georgia has collected it in Clarke, Putnam, and (?) Oglethorpe Counties in Georgia. We are much indebted to both of these gentlemen for furnishing us with excellent specimens. It was from one of Dr. Miller's plants that the drawing of *M. cordata* was made for our book (Coker & Totten, 1934, 1937).

In addition to these Georgia collections we have what we consider authentic records from other Georgia stations in Richmond, Columbia, McDuffie, Hancock and Bibb Counties.

Aside from the Michaux station on Horn Creek (now Edgefield County) the Elliott report, and the Nuttall and Gibbes specimens (no location other than South Carolina given), there is no record of a South Carolina discovery until Ashe in 1931 found *M. cordata* on the road to Graniteville across the river from Augusta.

In 1939 Mrs. J. D. F. Monts called attention to a small tree on the Monts farm in Richland County, South Carolina, about 14 miles north of Columbia. Notice of this appeared in the *Columbia State*, Aug. 9, 1939. Soon after this a number of trees were found in Newberry County, S. C., on the Nichols (or Lester brothers) land near Beaverdam Creek. All of these except one are small trees, some of them hardly more than seedlings. One, on the contrary, and unfortunately for the comfort of the taxonomist, is a very large tree, the largest at present known in the *Tulipastrum* group outside of the mountains. It is 20 inches in diameter at breast height and about 85 feet tall.

On a recent trip to Columbia (April 1942) the writer with Professor E. C. Coker of the University of South Carolina, Mr. C. H. Schaeffer, assistant state forester, and Mr. Fitzhugh McMaster visited this Newberry County station (April 18) and the writer brought back two small shoots which are now growing

on the grounds of the University of North Carolina. Professor E. C. Coker had previously brought in from this same location a young plant of the magnolia which at this time was blooming in the garden of the University of South Carolina although only 5½ feet high. (A News Release referring to this trip and other reports of *M. cordata* were sent out by Mr. Schaeffer on April 27, 1942, from the Columbia Office.)

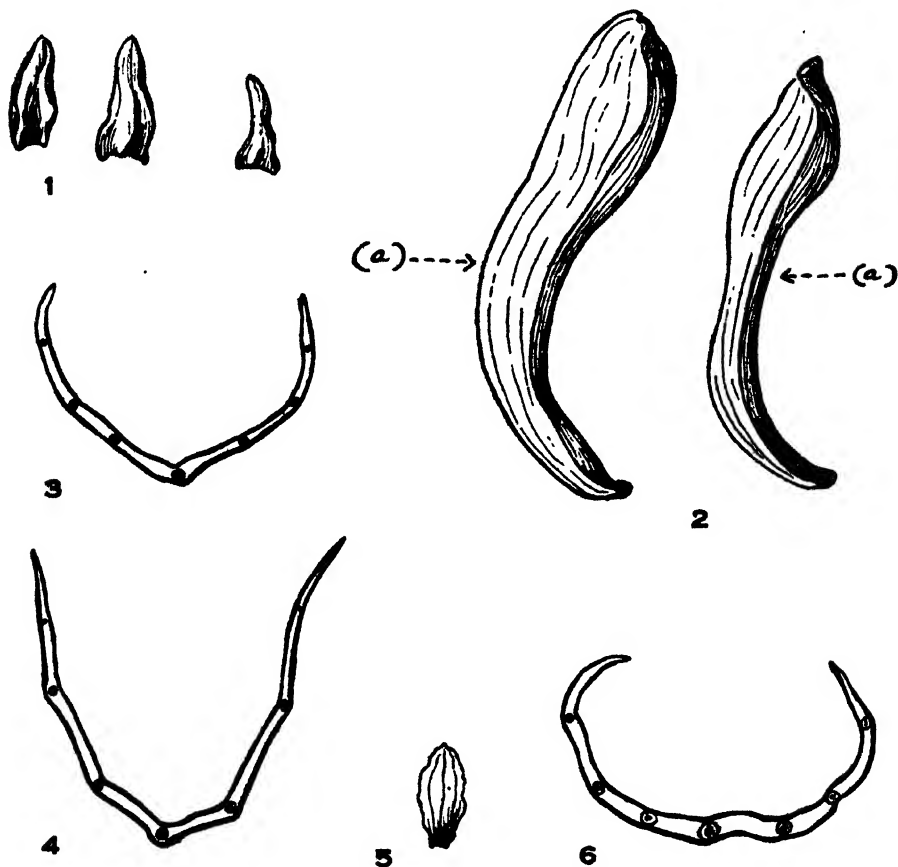
On the same afternoon Professor E. C. Coker, Mr. Schaeffer, and the writer went to the Monts farm to see the small tree above mentioned. It was in full bloom and buds just opening were carefully packed to be photographed. On our return to Chapel Hill two days later, the petals unfortunately had all opened and fallen off. This falling of the petals on almost the same day as the opening is characteristic of the *acuminata-cordata* group. Our photograph published herewith is from a specimen from this tree pressed at the time of the visit.

Prof. E. C. Coker has recently found several stations in the near vicinity of Columbia, from one of which we now have specimens. These are all represented on the map. Prof. Coker writes that at one of the stations, a hillside on the Du Bose place, there are 40 or 50 trees in an area of a few acres. Other South Carolina stations shown on the map have been reported to us by Mr. Schaeffer and Prof. Coker.

The extension of range into North Carolina in 1917 by Mr. J. S. Holmes has already been mentioned. In the following year Ashe says that *M. cordata* has been recorded from the central part of North Carolina in the extreme northwestern corner of Moore County or the adjoining part of Montgomery. We have not been able to confirm this record. Both of these stations are located on the extension of about the same topographical line and geographical area as Aiken and Columbia. It is the lower limit of the piedmont which is often referred to as the "fall line."

It may not be out of place to mention some other interesting plants that are rather closely associated with *M. cordata* along this fall line. In a letter of May 15, 1942, Mr. C. D. Beadle of Biltmore, N. C., writes that many years ago he and Mr. Cuthbert of Augusta found *Magnolia cordata* on the Falls of the Savannah River near Augusta—"near the magnolias was growing the rhododendron named by Small *R. Cuthbertii*, now our *R. minus* Mx." This rhododendron also occurs near Columbia and on May 5, 1937, Prof. E. C. Coker and the writer went to see a fine lot of it on the Le Conte farm about 10 miles east of the city. Here, near the rhododendron at the foot of a slope near a little stream we found a small tree of *Magnolia pyramidata*, a species never before reported from the state. At the top of the slope above this tree we also found the Black Sloe or Hog Plum (*Prunus injuncunda*) known before only from one station in South Carolina, in Edgefield Co. about 20 miles from where Michaux found *M. cordata* (Boynton, 1902). The Le Conte farm is only about 6-7 miles from one of our stations for *M. cordata*. A short note on our trip to this farm was published in the *Columbia State* of May 25th, 1937. Another rare plant found growing in near proximity to *M. cordata* in Richland and Newberry Counties, S. C., and in the vicinity of Athens, Ga., is Carolina Buckthorn (*Rhamnus caroliniana*).

*Magnolia acuminata* var. *aurea* Ashe, as it occurs in the Blue Ridge Mountains of North Carolina, is a large tree with small flowers about 4.5–5 cm. high; sepals small, unequal, green with yellow tint, the outer petals same color but slightly more yellow inside and toward the tip, inner petals clear golden yellow (Wax Yellow, Ridg.) tinted with green only toward the base. Leaves varying from



FIGS. 1–4. *Magnolia acuminata* var. *aurea*. Fig. 1, sepals, showing variation in size in the same flower; fig. 2, outer (left) and inner (right) petals; figs. 3 and 4, cross sections cut at (a) of inner and outer petals, respectively,  $\times 4$ .

FIGS. 5 AND 6. *Magnolia acuminata* var. *cordata*. Fig. 5, sepal; fig. 6, cross section of inner petal,  $\times 4$ .

All figures except those noted are natural size.

broadly ovate with rounded to truncate base and short apiculus to elliptic with cuneate base and longer point, at maturity usually softly pubescent beneath and glabrous above except on the larger veins. Twigs glabrous, buds densely pale-pubescent; cones usually small and deformed, often maturing only a few follicles, sometimes only 1–3; flowering from late April to late May, depending on the altitude. From the typical form of *acuminata*, these trees differ only in the much



smaller, more yellow flowers, and perhaps in the smaller and more deformed cones. (See our photograph and drawings of flower of var. *aurea* from Macon Co., N. C. For a good photograph of the typical *acuminata* enlarged, see Rogers, 1935; copied in Collingwood, 1941.)

*Magnolia cordata*, as we include it on our map, differs from var. *aurea* so far as we have yet found, only in the usually smaller size of trees,<sup>1</sup> pubescent twigs of first and usually second years, somewhat more consistently smaller and more broadly ovate leaves and in geographical range (lower altitudes). The base of the blade is by no means specific; it may be broadly rounded or more or less often strongly pointed. The habit of blooming again in the fall may also be important. We have no data regarding this point in var. *aurea*. The name *cordata* is a misnomer, as the blades are only rarely even faintly cordate at base, as is also true in the cultivated form. In fact they have no more tendency to this than the var. *aurea* or even the typical northern form. The writer has recently gone over the magnolias of this group in the New York Botanical Garden and finds that the leaves of typical *acuminata* are quite often broadly ovate with abruptly rounded or truncate base, as for example specimens from New York, West Virginia, etc. The only one of the *Tulipastrum* group in which the leaves may be really cordate is *M. acuminata* var. *ozarkensis* of which we have ample specimens. For this and other varieties see Ashe (1931). In this article Ashe describes a new variety, *alabamensis*, of *acuminata* to include the Alabama plants he had previously (1927) referred to *cordata*. Mohr's report of var. *cordata* may be this variety *alabamensis* or possibly var. *aurea*.

We think it worth while to quote here a few lines from Loudon regarding the typical *M. acuminata* as it occurred in cultivation in England in 1844 (note the leaf variations and early flowering from layers):

The leaves are from 6 in. to 7 in. long, and from 3 in. to 4 in. broad, upon old trees, but double that size upon young vigorous-growing plants. Michaux describes them as oval, entire, and very acuminate; but, in the seedlings raised in British nurseries, they are found sometimes ovate, nearly orbiculate, and cordate-acuminate. The flowers, which are 5 in. or 6 in. in diameter, are bluish, and sometimes white, with a tint of yellow. They have but a feeble odour; though, as they are large and numerous, they have a fine effect in the midst of the superb foliage. Plants raised from seeds do not usually produce flowers till they are eight or ten years old, when the tree will probably be from 15 ft. to 20 ft. in height; but plants raised from layers produce flowers in two or three years.

Loudon's two plates illustrating *acuminata* (pl. 7) and *cordata* (pl. 9) show very well the differences between the typical large-flowered *acuminata* with larger, more elliptical leaves, and the small-flowered *cordata* with broader and more rounded leaves.

In summing up all the evidence we have as to the position of our lower piedmont tree in the *Tulipastrum* group of magnolias, we arrive at the disappointing

<sup>1</sup>The big tree in lower Newberry Co., S. C., is about 85 ft. high and 5 ft. 7 in. in circumference (Schaffer); the record from upper Newberry Co. is of shoots from a stump 12 inches in diameter and the Clark Co., Ga., tree is 50 feet tall and 9 inches in diameter.

conclusion that *cordata* is only a rather vaguely defined, marginal extension of the southern yellow-flowered variety of *M. acuminata*. It is now evident that we cannot find a clear-cut geographical distribution for *cordata* as distinct from var. *aurea*. Its extension to the Athens, Ga., area brings it much closer to the mountains. The specimens from Clarke and Oconee Counties, Georgia, are good *cordata*, but the one from Oglethorpe County, adjoining, has glabrous twigs and a large cone (6.3 cm. long when dry), though the leaves are all typical *cordata*, very broad, one even suborbicular, with blunt bases and very short abrupt points. The tree is about 18 inches in diameter and 35 feet tall. We are indicating this station with a ? on our map. We now have a collection from Spartanburg Co., S. C., in the upper piedmont that might just as well be called *cordata* as var. *aurea*. It has small yellow flowers and *pubescent* twigs and rather narrow cuneate leaves. The farthest from the mountains that we know of for good var. *aurea* is not far from Greenville, S. C., on the Caesar's Head road, found by the writer growing so close to a young tree of *M. Fraseri* that the branches were touching. It was a small tree with yellow flowers and *glabrous* twigs. We are evidently dealing with a very variable group with extremes connected by a series of forms. This being so we can hardly be justified in calling the lower piedmont (fall line) tree anything more distinct than a variety, as Loudon long ago decided for the cultivated tree and as Sargent treated it in his first publications. This variety may be described as follows:

***Magnolia acuminata* var. *cordata* Sarg.**

A small tree rarely over 25-30 feet high and 8-10 in. in diameter, usually much smaller, rather symmetrically oval when not crowded; bark of trunk brown and deeply and closely ridged as in *M. acuminata*; terminal foliage buds in winter condition narrow, up to about 1.2 cm. long, and 3.5 mm. wide; lateral buds shorter and plumper; flower buds ovate, bluntly pointed, about 6-7 x 10-13 cm.; all buds densely white-tomentose; leaves typically ovate-elliptic, with or without a short abrupt apiculus, the base broadly rounded, usually about 8-13 cm. long, and 6-8 cm. broad (up to 15 cm. long and 10 cm. broad); under-surface closely pubescent, upper surface smooth at maturity, both surfaces densely pubescent when young, rather thick at maturity; petioles typically short, usually 1-1.5 cm., on strong shoots up to 2.5 (3) cm., minutely pubescent; twigs of the season pubescent throughout the year, also usually pubescent or at least roughened with the bases of hairs, on twigs of the preceding year; blooming in mid-April and again in the fall; flowers usually about 5 cm. high, and 5 cm. broad, petals 6, nearly upright from a curving base; outer petals broader, strongly cupped and folded inward, inner petals about the same shape, but less cupped; color of inner petals a clear golden yellow (Wax Yellow of Ridgway); color of outer petals less deep than inner (about citron yellow); calyx lobes glabrous, reflexed, more or less unequal, up to about 9 mm. long, 5 mm. broad, about color of outer petals; cone nearly always small and knotty, due to few follicles maturing, usually 2.5-3.5 cm. long; seeds orange-scarlet, about 1 cm. long, 8 mm. broad, maturing sometime in late August (some cones are so small that they have only one or two follicles maturing); inner bud scales brown, very thin, translucent, about 2 cm. long, glabrescent, thinly appressed-hairy toward the tips.

Confined to lower piedmont section from lower central N. C. to central S. C., central and upper middle Ga.; scarce and local, usually found on wooded hillsides along smaller streams together with the usual deciduous trees of the section. Pines, also, may not be far away.

DEPARTMENT OF BOTANY,  
UNIVERSITY OF NORTH CAROLINA,  
CHAPEL HILL, N. C.

#### LITERATURE LIST

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MAP  
of  
DISTRIBUTION  
of  
MAGNOLIA CORDATA

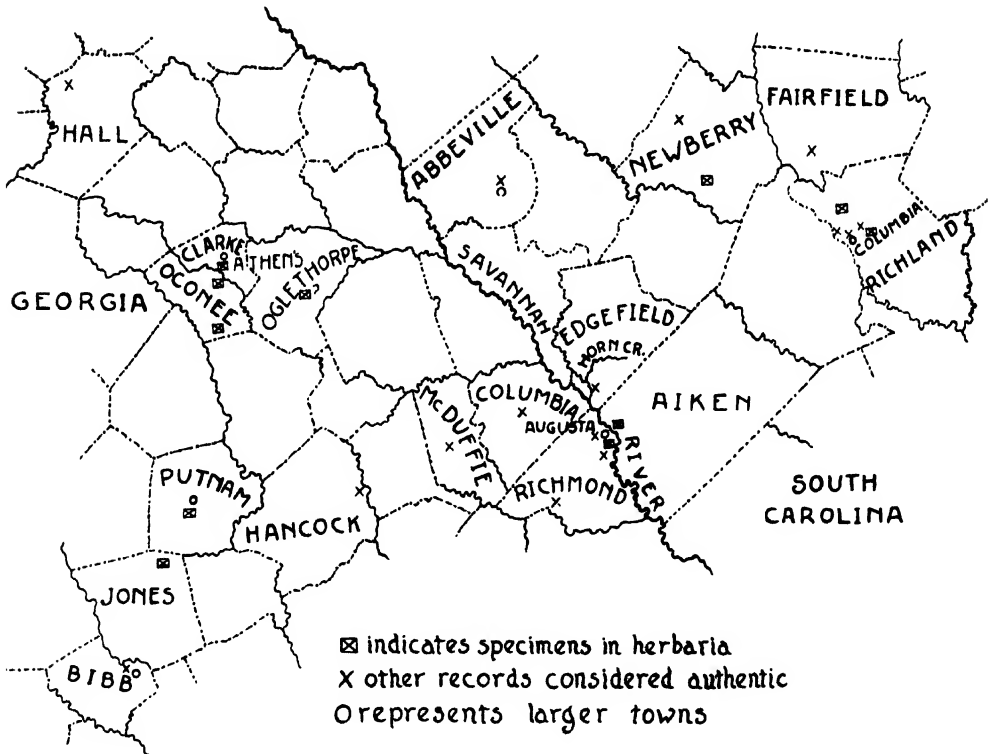
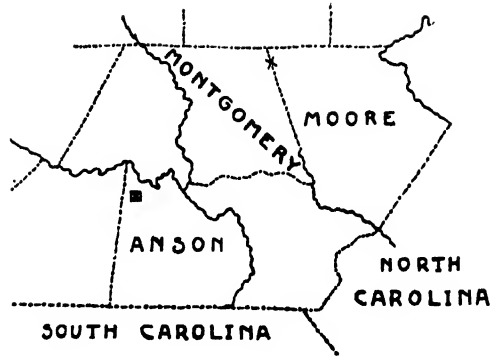
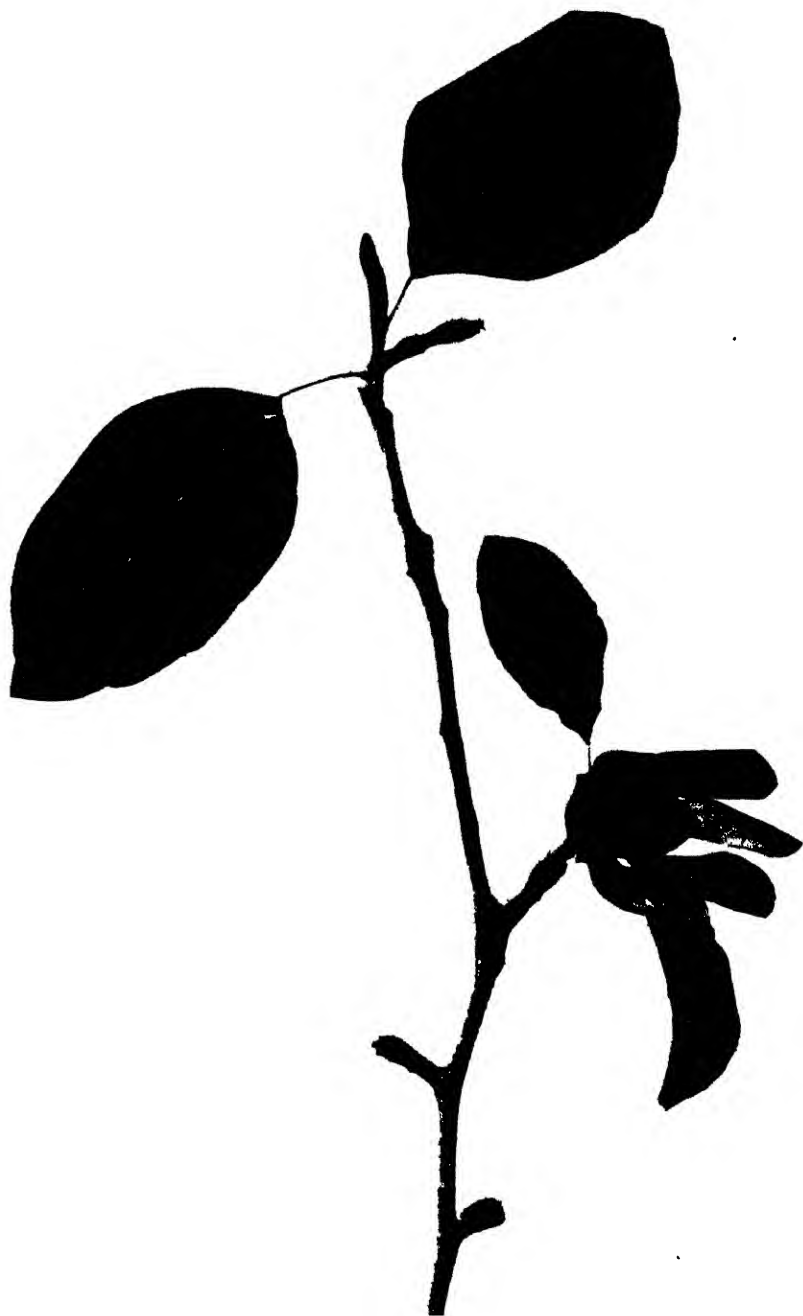




PLATE 18



*MAGNOLIA ACUMINATA* VAR. *CORDATA*

Richland County, S. C., April 18, 1942. Photograph of herbarium sheet showing flower,  $\times \frac{1}{4}$



PLATE 19



*MAGNOLIA ACUMINATA* VAR. *CORDATA*

Richland County, S. C., Aug. 8, 1939. Photograph of herbarium sheet showing two small open cones and seeds.





PLATE 20



MAGNOLIA ACUMINATA VAR. AUREA

Macon County, N. C., May 25, 1942 One petal removed from lower flower  $\times \frac{1}{2}$



## A NEW RAFINESQUE LETTER

BY PHILLIPS RUSSELL

A hitherto undiscovered and unpublished letter, amounting almost to an autobiography, of Charles S. Rafinesque has been found in an old letter file belonging to the archives of the University of North Carolina at Chapel Hill. It consists of an application for the then vacant professorship of modern languages in that institution. It was written in 1826, the same year<sup>1</sup> that this eccentric scientist of the early 19th century in America departed angrily from Lexington, Ky., where he had been a member of the faculty of Transylvania University, and returned to Philadelphia, where he eventually died in the bitterest poverty.

If no other evidence existed, this letter would be sufficient testimony concerning certain Rafinesque traits: his tendency to be temperamentally difficult, his inclination to be boastful, and his pride in his own versatility. It is also proof that Rafinesque had not the complete knowledge of the English language of which he boasts, for the style is that of a foreigner.

The letter, which was addressed to Ichabod Wetmore of Raleigh, N. C., chairman of a trustee committee appointed to choose the new professor, is herewith printed so as to show Rafinesque's own spelling, grammar, punctuation, under-scoring, and capitalization. It will be noted that he was misled by the address of the chairman into thinking that the University was located at Raleigh.

Lexington, Ky 22d April 1826

I. Wetmore Esq  
Raleigh N.C.

Sir—I write you in consequence of having seen an advertisement in the National Gazette, concerning a Vacancy of the Professorship of Modern Languages in the University of N. Carolina.

I beg leave to apply for that appointment. The claims which I can state in my behalf are the following. I have been for six years Profr of Modern Languages in the Transylvania Univ of Lexington. I have taught there the french, Spanish & Italian, but I am going to leave this Institution where I have not been adequately rewarded.—I was born of a french father & a german Mother. I was raised in France and Italy; I have been in Spain & a portuguese Colonys—I can teach the French, Spanish, Italian & Portuguese. I have not merely a *familiar acquaintance* with those languages; but a *complete mastership* of the French, Italian, and English, so as to be able to write in them fluently both in *prose* and in *verse*. My knowledge of Spanish & Portuguese is more limited, for want of practice; but I know those languages and their grammar as well as our Teachers of greek & Latin know these. I have also a general knowledge of Latin, greek &c, and a smattering of hebrew, Arabic, German &c. To which I may add a philological knowledge of comparative Linguistics or all languages compared

<sup>1</sup>It is erroneously stated by R. E. Call, *Life and Writings of Rafinesque*, pp 49 and 119, that Rafinesque left Kentucky in 1825, although the year is correctly given on p 42

It may be of interest to readers that while Rafinesque did not obtain the position applied for it was given to another naturalist, Nicholas M. Hents, the famous student of spiders. —Ed.

together—as can be proved by my printed Table of the compared Roots of all Languages.

I have written several works & Pamphlets, upwards of twenty, in french, Italian, English & Latin—On Arts & Science, Literature, &c—and I have by me many additional manuscripts, among which a Comparative Grammar & Vocabulary of the French, Italian, Spanish & Portuguese, besides several of those Languages & Dialects. I know their Literature &c I can read, construe, translate &c from each into each other.—The English I know completely also, having come young into America, & I speak it without a foreign accent. The french I speak purely, without local accent. The Italian I speak with the purest Tuscan & Roman Accent &c I can deliver Lectures extempore in French, Italian & English. I can even compose extempore verses or *Improvvisare* in Italian. And I can sing in Italian, french, Spanish, English, &c.

These qualifications embolden me to offer my services to the University of North-Carolina, as a Professor of Modern Languages, which I can fill with skill and credit.—Altho' your Advertisement does not state that references are needed, yet as this is often a requisite, I can in that case give satisfactory references & evidences of my attainments.

I have one hundred friends who could recommend me, and if high names may have any influence, I can refer to Dewitt Clinton of Newyork, Dr Samuel L. Mitchell of Do—Zaccheus Collins & William Rawle of Philadelphia—Dr James Smith of Baltimore—Henry Clay & Timothy Winn, Washington City, who all know my attainments & standing.

I am also known to them & the public as a Botanist, a Naturalist, a historian, an antiquarian, an Engineer & a Draftsman—I have never visited North Carolina & should wish to explore it also as a Botanist, historian &c: this is an additional Inducement for my application.

I began this letter in Lexington & perhaps shall conclude it at the harrodsburg Springs where I am going on a short visit. I propose removing to Philadelphia next month, with my Library & Cabinet which has already been sent on packed up in 40 boxes & Trunks.—Your answer must be directed to *Philadelphia*. where I shall be in June, after an exploring Journey throuth Ohio & Virginia.

Hoping that what I have stated may prove satisfactory, I conclude by advising you that my Statements have been fair and true. If any doubts are felt, I am willing to be appointed for only one year, so that we may all know whether we suit as well as contemplated, & and that I may know whether Raleigh will prove sufficiently agreeable for a permanent Residence, as I hope it may; but I thought so of Lexington once, and great promises were held to me, which have been broken; and I have had to move & remove with my large apparatus & Library at great Expence; which I wish to avoid in future.

I remain very respectfully yours—

C. S. Rafinesque  
A.M.—Ph.D. &c

(Postmarked Harrg. K(y) Apr 27)

JOURNAL  
OF THE  
**Elisha Mitchell Scientific Society**

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December, 1943

No. 2

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PROCEEDINGS OF THE FORTY-SECOND ANNUAL MEETING OF THE  
NORTH CAROLINA ACADEMY OF SCIENCE

DUKE UNIVERSITY, DURHAM, NORTH CAROLINA

Reported by BERT CUNNINGHAM, *Secretary*

The forty-second annual meeting of the North Carolina Academy of Science was held at Duke University, Durham, April 30 and May 1, 1943.

The first general session was called to order by President H. F. Prytherch at 9:30 A.M. The presentation of papers began at once and continued until 10:30 when Dr. Milton J. Rosenau was called upon to preside over the "Symposium on health and the war." The morning session closed at 12:30.

Simultaneously the section on Biochemistry and Physiology met, and some twelve papers were given and discussed.

The second general session was called to order by the President at 2:00 P.M. and continued with the presentation of papers until 4:00 P.M. when a recess was called to give the membership an opportunity to visit the demonstrations and exhibits.

The Academy reconvened at 4:30 P.M. in a business session with President Prytherch in the chair. The minutes of the 1942 meeting were approved as published in the Mitchell Journal. Reports of the various committees were called for. The reports had been mimeographed and were distributed throughout the day, so that it would be unnecessary to read them in full before the Academy. The reports have been condensed for publication, but copies of the full reports are available upon request.

REPORT OF THE EXECUTIVE COMMITTEE

This Committee transacted considerable business by mail, and held its annual meeting Thursday night, April 29. There are certain provinces in which the Committee has power to act, but must report its action to the Academy. The Committee therefore reports that:

1. It has elected fifty-two new members. The list appears below.
2. It has accepted the invitation of Dean Harrelson on behalf of State College to hold the next annual meeting of the Academy at that institution.
3. It authorized the Secretary to expend not more than \$125 for secretarial aid for the current year.

4. It has accepted the responsibility of administering the Forestry Essay award fund, provided by the N. C. Forestry Association.

5. It has authorized the payment of such bills as were presented to it by the Treasurer.

6. It has added several late titles to the program. These are indicated on errata sheets.

7. It has authorized the Secretary to prepared mimeographed lists of the membership as of June 1, 1943, for distribution to interested parties.

8. It authorized that a resolution to remit fees for members in the armed forces be submitted to a mail ballot of the membership of the Academy.

This part of the report was accepted by the Academy.

The Executive Committee is also expected to consider matters that concern the welfare of the Academy and make recommendations to the Academy. The following recommendations were considered individually.

1. That a system of symbols be used in the preparation of our rolls, thereby indicating the group(s) in which each individual member is interested. The system used by the A.A.A.S. should be followed, including the date of admission to the Academy. Passed.

2. That the Treasurer's Report as of June 1, 1943, shall be submitted to the Auditors and published along with the Auditors' report as a part of the Proceedings of this meeting. Passed.

3. That the High School projects be continued as set up at present and the \$20 project award be continued. Passed.

4. That a permanent committee on life membership be established. This committee should consist of three members elected for a term of three years. One new member to be elected by the Academy each year. Passed.

5. That action be taken toward a joint meeting of the North Carolina Section of the American Chemical Society so that members of either group may appear on the common program without becoming members of both organizations. The Executive Committee or some designated members should be authorized to act for the Academy. Passed.

6. That a Publications Committee be set up to consider matters related to the publication of the Proceedings and other contributions that may seem worth while. Passed.

7. That a special committee be set up to study the problem of college science clubs and their affiliation with the Academy. Passed.

8. That the secretaries of the various sections be made responsible for arranging the program of their individual sections. Passed.

The report was then adopted as a whole.

#### LIST OF NEW MEMBERS

Baity, Herman Glenn, Public Health, U. N. C.

Baxley, Miss Hartlee, Agriculture and Engineering, State College.

Beal, J. A., Forestry, Duke.

Brauer, Alfred T., 408 North Street, Chapel Hill.

Browne, O. H., 1206 6th Street, Hickory.  
Coon, Beckford F., Zoology, State College.  
Davison, Verne, Soil Conservation Service, Spartanburg, S. C.  
Dick, MacDonald, Duke.  
Edwards, Ross I., Camp Lee, Va.  
Emory, S. T., Geography, U. N. C. (Reinstated)  
Findlay, John D., Conservation and Development, Raleigh.  
Fishman, William H., Biochemistry, Bowman Gray School of Medicine.  
Freeman, John A., Wake Forest.  
Graham, Robert S., Wake Forest.  
Grollman, Arthur, Bowman Gray School of Medicine.  
Grubb, Paul F., Catawba College.  
Hagquist, C. W., Elon College.  
Hussey, Kathleen L., 112 Montgomery St., Raleigh.  
King, J. E., Zoology, U. N. C.  
Koch, Sigmund, Psychology, Duke.  
Kulash, W. M., State College.  
Lacey, O. L., Psychology, W. C. U. N. C.  
Lewis, William M., 2710 Rosedale Avenue, Raleigh.  
Liebman, Emil, Zoology, Duke.  
Lowenbach, Hans, Duke Hospital.  
Lyle, James A., Botany, State College.  
Lyman, R. S., Duke Hospital.  
McCurdy, Harold G., Meredith College.  
Miller, Edwin L., Jr., Box 1368, Raleigh.  
Mouzon, James C., Physics, Duke.  
Owens, Henry G., 1301 Ebert Street, Winston-Salem.  
Parker, Herman M., Wake Forest.  
Patterson, Grover, Catawba College.  
Peeler, George D. M., Catawba College.  
Peterson, W. J., Nutrition, State College.  
Phillips, Mrs. Margaret C., Elon College.  
Pye, Miss O. Florence, W. C. U. N. C.  
Radford, A. E., 22B Macomb Street, Plattsburg, N. Y. (Reinstated)  
Reddish, P. S., Box 141, Cary, N. C.  
Reid, W. C., State College.  
Stephens, James L., 1200 Chestnut Street, Lumberton.  
Sullivan, Charles S., Zoology, State College.  
Trentham, S. O., Mars Hill College (Reinstated)  
Wallin, Guy R., Biochemistry, State College.  
Whitehead, L. C., U.S. Fish & Wild Life, State College.  
Williams, David V.P., Physics, Catawba College.  
Wilson, A. J., Chemistry, State College.  
Wilton, Oera C., East Carolina Teachers College.  
Wing, Merle W., Entomology, State College.  
Wolff, William A., Pathology & Toxicology, Bowman Gray School of Medicine.  
Phy-Chem Club, Durham High School.  
Zoology Field Club, Womans College U. N. C.

The Secretary reported that the ballot for remission of fees of members in the armed service for the duration was circulated among the membership and passed by a large majority.



### REPORT OF THE REPRESENTATIVE TO THE COUNCIL OF THE AMERICAN ASSOCIATION

Since the A.A.A.S. did not hold its annual meeting this year, some of the necessary business has been transacted by mail. The President of the Association has been elected in this manner. Several resolutions have also been submitted and some passed. Reference will be found to these from time to time in Science and the Science Bulletin.

BERT CUNNINGHAM

The report was adopted.

### REPORT OF THE REPRESENTATIVE TO THE ACADEMY CONFERENCE

The Academy Conference did not convene this year, hence there is nothing to report.

BERT CUNNINGHAM

The report was adopted.

### REPORT OF THE RESEARCH GRANTS COMMITTEE

This Committee had not filed an official report up to the time of going to press. The Secretary suggests that requests for this grant be closed as of June 1, 1943.

This report was adopted and there is appended hereto a later report of the committee.

The Research Grants Committee, consisting of C. F. Korstian, O. C. Bradbury, J. P. Givler, and J. N. Couch, Chm., has considered the A.A.A.S. grant. Three applications were received, two of which have been withdrawn in favor of the youngest applicant. The Committee has made the award to Mr. William M. Lewis for his study on nesting habits of gray squirrel and wood duck by the use of artificial nesting boxes.

JOHN N. COUCH, *Chairman*

### REPORT OF THE TREASURER

It is quite impossible to make a Treasurer's report at this time of the Academy meeting that would indicate the financial status of the Academy. Dues that have been received during the month, as well as bills paid during the same time, have not yet appeared upon the bank statement. Probably a number of members will pay dues at this meeting, still others will remit before June 1. The Treasurer therefore recommends that the final report be based upon the bank statement of June 1, 1943.

It is also recommended that such bills as are incurred during this meeting shall become valid when certified by the retiring president. It is further recommended that the report of the Treasurer and the Auditing Committee be published as a part of the Proceedings of the Academy for 1943.

The report was adopted.

## FINANCIAL STATEMENT AS OF JUNE 1, 1943

*Summary of Accounts*

## Receipts

Bank Balance (checking acct.) 6/1/42.....	\$132.53
Receipts.....	720.54
Transferred from savings account.....	222.00
	<hr/>
	\$1075.07

## Expenditures

Bonds.....	222.00
Operating costs.....	707.28**
	<hr/>
	\$929.28
Balance in checking account.....	145.79
	<hr/>
	\$1075.07

*Savings Account*

## Chapel Hill Bank\*

Balance 1/1/42.....	\$424.12
Interest 1/1-7/1/42*.....	3.16
	<hr/>
	\$427.28

## Fidelity

Deposited 7/1/42.....	427.28
Withdrawn to purchase bonds 7/1/42.....	222.00
	<hr/>
	\$205.28
Interest 7/1/42 to 4/1/43.....	3.07
	<hr/>
Balance as of April 1, 1943.....	\$208.35

## AUDITORS' REPORT

On this 5th day of June, 1943, we have examined this account and found it to be correct.

(Signed) O. C. BRADBURY

GEO. C. MACKIE

W. E. SPEAS, *Chairman*

A detailed report is available to any member desiring it.

## PRELIMINARY REPORT OF THE POTEAT AWARD COMMITTEE

The Committee has met by correspondence and the chairman has consulted with some of the members of the 1942 Poteat Award Committee and with other Academy members interested in working out some more feasible plan by which satisfactory decisions may be reached in the selection of an outstanding paper in

\* This account was transferred from the Chapel Hill Bank to the West Durham Fidelity Bank on this date.

\*\* Operating receipts for the current year exceeded operating cost by \$13.26.

some field. Following are some of the chief suggestions which have been considered.

1. Department heads be asked to suggest persons whom they think will have unusual papers. It would, of course, be nearly as embarrassing for a department head to nominate one of his own students as for him to propose his own paper. However, it is suggested that department heads and other Academy members deem it their duty to report to the Secretary of the Academy or to the Award Committee certain papers which they think desirable for consideration for the award.

2. The easiest way for the Committee would be to place on the general session programs those papers deemed suitable for consideration for the award, but this would not be to the best interests of either the general sessions or the special section meetings, since it would prevent the more technical papers being presented before the few who are particularly interested in them and would deny the writer the benefit of desirable rigorous technical criticism. At the same time, this would crowd out desirable general papers.

3. Academy nominations by secret ballot, to aid the Committee's choice. This seems to have some merit, but would again impose the limitation of general sessions, since it would be next to impossible to evaluate the suggestions of the members attending the various special sections. It would seem desirable, however, for the chairman of each section to notify the Award Committee of any suitable papers.

4. It has been proposed that candidates wishing to have their papers considered, submit their manuscripts or complete abstracts at least two weeks before the Academy meeting, but this suggestion of competitive contest does not seem to be either practical or desirable. However, if it were possible, it would seem helpful if abstracts of all papers were placed in the hands of the Secretary, well in advance of the meeting.

Since the Poteat Award cannot be made until after all papers have been presented, your Committee wishes that the Secretary be instructed to include the report of the award in the Proceedings of the Academy.

The report was adopted.

It was moved and carried that the Poteat Committee consider the advisability of changing the award, so that it would be a research grant rather than an award for work already completed. There was considerable discussion of the proposed change, and the Committee is expected to make a report sufficiently early so that if any change is made it can be announced early in the fall.

Mr. Bird of Phipps and Bird, the donors of the award as well as the Inter-Academy Award, was present at the meeting and indicated a willingness to do whatever the Academy deemed best. He also announced the discontinuance of the Inter-Academy Award, which he felt had not accomplished the purpose for which it was designed. Members of the Academy who have worked with the project concurred in this opinion.

The Academy instructed the Secretary to include in the proceedings of this

meeting the announcement of the winner of the Poteat Award. This year Dr. H. S. Perry of the Botany Department of Duke University was given the award for his paper on "Control of starchy contaminations in sweet corn by the use of the 'gamete' gene."

#### REPORT OF THE CONSERVATION COMMITTEE

In reference to the proposal endorsed by this Academy and by our sister Academy of Virginia that the Dismal Swamp be acquired by the Federal Government and maintained and administered as a National Forest, your Committee reported last year that "The acquisition and protection of the Dismal Swamp seems necessarily postponed until the war is over, that is, unless it can be conclusively shown that a fire burning in this swamp, so close to the Norfolk area, would seriously disrupt Army, Navy, or industrial activities by covering the region with a pall of smoke which might, in a dry season, last for weeks. A suggestion has already been made to the Government that steps to prevent such a catastrophe might well be considered a necessary part of our war effort."

Since that time both the Army and Navy officials in vigorous protests to Governor Broughton, have insisted upon the prevention of forest fires in the Dismal Swamp as well as in similar areas near to troop concentrations on other parts of our coast. This has resulted in the establishment of organized forest fire protection of the Dismal Swamp under the supervision of the Forest Fire Control officials of the two states, the Federal Government paying all costs. This protection went into effect last August with an estimated budget to cover cost during the present fiscal year of some \$45,000. The protective personnel for the North Carolina half of the swamp consists of a Swamp Ranger supervising the whole swamp, whose salary comes one-half through Virginia and the other through this state, a District Ranger, resident at Elizabeth City, four patrolmen on an annual basis and four on six months basis, with four stand-by crews of five men each. In addition to this, considerable heavy equipment and other fire fighting tools are being purchased to carry on this protection throughout the war period. It seems to us that this is a very decided step towards the attainment of our goal; for while the funds are now from war appropriations, it will be necessary later on to decide whether this effort is to be continued or abandoned. It seems most likely that the Government will decide that the protection of the United States will demand the continued prevention of fires in this swamp.

#### *The Wood or Summer Duck*

In previous years this Committee has dealt largely with the conservation of species and groups of plant life, but the preservation and perpetuation of animal species is certainly of equal importance. Again we find our beautiful Wood Duck marked for slaughter in the United States, although still under protection in Canada. The Fish and Wildlife Service, now in the U. S. Department of the Interior, for the first time in twenty-six years has made it possible to shoot Wood Duck in this and presumably all other states.

Nearly thirty years ago T. Gilbert Pearson, former President of the National Audubon Society, wrote in "Birds of North Carolina" as follows: "Calloused indeed is the heart of the hunter who can gaze unmoved upon the matchless beauty of a male Wood Duck. . . . Wood Ducks are choice food, and as a result of their constant persecution are rapidly becoming exterminated in many parts of the State, a fate doubtless being hastened by the draining of ponds and swamps. Their numbers are so reduced that, in my opinion, their killing should be prohibited by law at all times."

It was shortly after this was written that the International Migratory Bird Law went into effect and under this the taking of Wood Duck anywhere in the United States or Canada was prohibited. In March, 1939, J. W. Kistler, Field Biologist of the North Carolina Department of Conservation and Development, wrote in North Carolina Wildlife Conservation: "This protection of the Wood Duck has resulted in this species staging a comeback and during the autumn in some locations these ducks may be seen in flocks of a hundred or more."

Throughout the seventy day period of legal duck shooting, the gunner under present Federal regulation is limited to one Wood Duck a day. With such license it will not take long to decimate seriously the supply of these beautiful birds, made tame and confident by protection. This permission to shoot the Wood Duck is admittedly granted because the gunners do not know well enough the distinctively marked ducks. Apparently, the ducks are sacrificed to keep the careless sportsmen from being penalized. Such regulations apparently take little thought of perpetuating the species.

While this present lamentable situation has only been in operation through one hunting season, the Director of the State Museum, because of the number of these ducks brought in to be mounted, has expressed the opinion that much of the benefit of twenty-six years of protection has been lost by the destruction of the past winter. If the Wood Duck is not to take its place with the extinct Carolina Paroquet, the Wild Pigeon, the Heath Hen and the nearly extinct Ivory-billed Woodpecker, immediate steps must be taken again to place this species under full protection.

Your Committee therefore recommends that the following resolution be adopted:

"Whereas, the ranks of the Wood or Summer Duck (*Aix sponsa*) have been reported as much reduced during the open hunting season allowed by Federal Regulation for the winter 1942-43, and

Whereas, the North Carolina Academy of Science is deeply interested in the perpetuation of our species, especially those of such public interest and value, as well as pronounced beauty, as the Wood Duck;

Therefore, be it resolved, that this Academy request the Fish and Wildlife Service of the Department of the Interior to restore this bird to its former position of complete protection throughout the United States."

(Signed) C. F. KORSTIAN

H. H. BRIMLEY

J. S. HOLMES, *Chairman*

The report was adopted and the resolution was adopted on a separate ballot.

#### REPORT OF THE HIGH SCHOOL SCIENCE COMMITTEE

The Committee carried on its usual activities though with rather a slow start. The principal difficulty was getting in touch with clubs. Ultimately we corresponded with twenty-four organizations.

As far as the Committee knows no local fairs were organized this year. Unquestionably the war conditions are directly responsible for this.

Science Clubs of America, sponsored by Science Service, cooperated with the Committee this year to the extent of furnishing their list of clubs. There are about 45 such clubs in the state. We discovered that some of these are completely dormant.

Clubs affiliating with the Academy have had their choice of "Nature Magazine", "Fauna", "Natural History", or "Popular Mechanics." This is a decided improvement over our offer of the "Elisha Mitchell Journal" which is of no use to them.

The Committee feels that some sort of an inter-club publication would be of value. A year ago the Academy authorized the Committee to solicit funds for such a publication and if such funds became available to proceed with publication. Though it did not appear feasible to go ahead with this, this year, the committee would like the authorization renewed.

The Committee is delighted to announce the addition of a set of lantern slides on "The Small Garden" which became available just in time to contribute to this spring's victory garden campaign. The set was presented to the Academy by Mr. Lewis Watson of the Department of Horticulture, N. C. State College. Once our contacts were made the slide sets were in almost constant use.

The Committee is glad to report that the North Carolina Forestry Association has continued its award for a meritorious essay written by a high school student on some subject related to forestry. The announcement of the winner will be made during the meeting.

The Committee recommended to the American Association for the Advancement of Science, that Helen McNaull of Canton High School and David Watters of Hugh Morson High School, Raleigh, be made Honorary Junior Members of the Association. The recommendation was accepted by the Association and they were duly elected to membership.

At the time of the preparation of this report the Committee has no information concerning the possible entrants for the Academy award. Whether or not there are any, the Committee suggests the continuation of the project.

The Committee recommends:

1. That the Academy renew its authorization for the High School Committee to solicit funds for an inter-club publication.

2. That all projects now under way be continued, including the \$20 award.

3. That the Academy express its appreciation to Mrs. Lewis Watson, the North Carolina Forestry Association, and the State Department of Education for their splendid cooperation with the High School Committee.

The report and recommendations were adopted.

M. L. BRAUN  
ELIZABETH CONNER  
C. F. DODSON  
W. S. DELOACH  
J. H. HIGHSMITH  
M. F. BUELL, *Chairman*

#### REPORT OF THE LEGISLATIVE COMMITTEE

The Chairman and President Prytherch brought our program to the attention of Governor J. M. Broughton and Representative D. L. Ward of New Bern. They were both much interested. On April 15 your Committee Chairman discussed the situation with Governor Broughton. The Governor has promised to bring our needs before the State Planning Board when it is set up by him after July 1, and asked the Chairman to write him concerning the needs of the Academy on July 15. The following memorandum was left with the Governor:

The North Carolina Academy of Science, with some three hundred members, drawn from the educational and industrial research personnel of the State is in need of a special fund to be used to publish the results of research and for Grants-in-Aid in the State.

The sum deemed necessary is two thousand dollars per year.

This sum to be administrated entirely by the North Carolina Academy of Science either by the Executive Committee or by a standing committee created entirely to administer this fund. The Academy being responsible to the State for the handling of the fund.

All publications and grants-in-aid would acknowledge the State aid making such publications and/or grants-in-aid possible.

The report was adopted.

#### *Additional Report of the Legislative Committee*

The Kilgore Bill (Senate 702)—"To mobilize the scientific and technical resources of the Nation, to establish an Office of Scientific and Technical Mobilization, and for other purposes" received by the Committee and presented to the business meeting was referred back to the Legislative Committee with power to act.

The Committee regrets that our fifth recommendation has failed to elicit any response from our membership.

B. C. BURGESS  
B. W. WELLS  
M. J. ROSENAU  
WILLARD BERRY, *Chairman*

## REPORT OF THE SPECIAL COMMITTEE ON LIFE MEMBERSHIPS

Your Life Membership Committee recommends that eligibility for life membership in the North Carolina Academy of Science be based on the following criteria:

1. Twenty years of membership in the Academy.\*
2. Notable service to various scientific organizations.
3. Worthy contributions to science, in research, teaching, or public service.

The report was adopted.

The Committee presented the following for election to Life Membership:

*James Bell Bullitt*, Professor of Pathology, University of North Carolina. Born, Louisville, Ky., Jan. 18, 1874. A.B. Washington and Lee, 1894, A.M., 1895; M.D. Virginia, 1897. Demonstrator anat., Virginia, 1898-1903; prof., Mississippi, 1903-13; path., North Carolina, 1913-; Major, U.S.A., 1918-19. A. A.; Soc. Clin. Path.; Am. Med. Asn.; Micros. Soc.; Col. Physicians; Asn. Mil. Surg.; Anthropol. Asn.; South. Med. Asn.; N. C. Acad. Hookworm; trichinosis; tuberculosis; neoplasms. Joined the Academy in 1920; President, 1933.

*Frank Kenneth Cameron*, Professor of Chemistry, University of North Carolina. Chemistry. Born, Baltimore, Md., Feb. 2, 1869. A.B. Hopkins, 1891, Ph.D. 1894. Sage fellow and instr. org. chem., Cornell, 1894-95; assoc. prof., Catholic Univ., 1895-97; asst. physical chem., Cornell, 1897-98; expert, U. S. Dept. Agr., 1898-99, soil chemist, 1899-1915; consulting chemist and chem. engineer, 1915-; prof. chem., North Carolina, 1926-; A. A.; Chem. Soc.; Chem. Eng. Heterogeneous equilibria; films; colloids; chemistry of minerals, soils, plants, metallurgy and industrial processes. Joined the Academy in 1928.

*William de B. MacNider*, Kenan Research Professor of Pharmacology, University of North Carolina. Pathology, Pharmacology. Born, Chapel Hill, N. C., June 25, 1881. M.D. North Carolina, 1903; Sc.D., Med. Coll. of Virginia, 1933; LL.D., Davidson Coll., 1934, Chicago, Western Reserve. Asst. Biol., North Carolina, 1899-1900, anat., 1900-02, clin. diagnosis, 1902-05; prof. pharmacol., 1905-18, Kenan prof., 1918-24, Kenan research prof., 1924-, dean med. sch., 1937-40; lecturer, Harvey Soc., 1923-29; Nat. Board Med. Examiners. Gibbs prize, N. Y. Acad. Med., 1930; medal, South. Med. Asn., 1933. A. A.; Soc. Pharmacol. (assoc. ed., "Jour.," treas. and councilor, pres., 1932); fellow Am. Med. Asn. (chairman, sect. on pharmacol., 1927); fellow, Coll. Physicians; Am. Physicians; Asn. Path. and Bact.; Soc. Exp. Path.; Physiol. Soc.; Soc. Exp. Biol. (ed. board); Soc. Biol. Chem.; Asn. Anesthetists; Nat. Anesthesia

\* It is understood that there are circumstances in which the time requirement may be waived so far as membership in the North Carolina Academy is concerned. For example, one may be highly worthy in other respects, but may have been within the state only fifteen years. In such case the time limit may be waived. (Interpretation by Secretary.)



Research Soc. (pres.); N. C. Med. Soc. (pres., 1925); N. C. Acad.; Int. Anesthesia Research Soc. (hon. pres., 1934). Pharmacology of the kidney; experimental nephritis; acid-base equilibrium of the blood in liver degeneration and repair, in nephritis and in pregnancy; toxicity of uranium; toxic effect of general anesthetics; nephropathy in the dog; the development of acquired resistance of fixed tissue cells after injury on the part of the liver and kidney. Joined the Academy in 1911.

*Zeno Payne Metcalf*, Dean, North Carolina State College. Entomology. Born, Lakeville, Ohio, May 1, 1885. A.B. Ohio State, 1907; Sc.D. Harvard, 1925. Instr. entom., Mich. State Coll., and asst. entomologist, Exp. Sta., 1907-08; asst. entomologist, State Dept. Agr. N. C., 1908-12; prof. zool. and entom., N. C. State Coll., and entomologist, Exp. Sta., 1912-, director instructions, sch. agr., 1923-. Staff, lake lab., Ohio, 1916, 1918; Mich. Biol. Lab., 1921; visiting prof., Duke, 1935-36. Ed. board, "Catalog Hemiptera of World"; sect. ed., "Biol. Abstracts," 1926-; ed., "Ecology," 1935-37. A. A.; Entom. Soc.; Asn. Econ. Entom.; Micros. Soc. (v.-pres., 1922, pres., 1927); Ecol. Soc.; Soc. Mammal.; Soc. Ichthyol. and Herp.; Limnol. Soc.; Ornith. Union; Wilson Ornith. Club; N. C. Acad. (v.-pres., 1914, pres., 1921); Ohio Acad. Economic entomology; morphology of Homoptera; classification of Homoptera of the world; zoology of North Carolina. Joined the Academy in 1909.

On motion the above were elected to life membership.

On motion the Academy set up a permanent committee to make recommendations for life membership. The committee is to consist of three members, each serving for a period of three years and one being elected each year.

EDNA ARUNDEL  
H. W. FERRILL  
G. C. MACKIE  
C. H. SATTERFIELD  
A. S. PEARSE, *Chairman*

#### REPORT OF SPECIAL COMMITTEE ON PRIMEVAL FOREST

Your Committee has nothing to report on this project of the Academy. Through an interested party it has been learned that some timber has been sold from the Ravenel property but the Primeval Forest has not been touched. This seems to indicate that the owner is unwilling to sell the property for the timber upon it, as the prices of standing timber are not likely to be any higher than at present, and when the war is over they will undoubtedly decline. There seems nothing that the Committee or the Academy can do to further this project at the present time.

O. C. BRADBURY  
H. J. OOSTING  
C. J. SPENCER  
A. F. THIEL  
LIONEL WEIL  
B. W. WELLS  
J. S. HOLMES, *Chairman*

The report was adopted and the Committee was discharged.

Dr. E. W. Gudger, who had been appointed to represent the Academy at the Torrey Botanical Society Anniversary, reported that he attended and was duly registered as our representative.

The report was adopted.

The Academy has been unusually affected this year by deaths among its membership. The following resolutions concerning these departed members were presented to the Academy.

Dr. John Richard Carpenter, who passed away at the Duke Hospital July 16, 1942, was born at Oshkosh, Wisconsin, March 19, 1911. His parents moved, two years later, to their present home in Grand Rapids, Michigan. In June, 1928, he graduated from the Ottawa Hills High School of his home city. His first two years of collegiate training were secured at the Grand Rapids Junior College whence he transferred to the University of Illinois from which he was graduated, with honors in zoology, in June, 1932.

After two years of graduate work, one at the University of Illinois and the other at the University of Oklahoma, he received his M.S. degree. Then as part time assistant in zoology he spent the year 1934-35 at the University of Oklahoma and qualified for a Rhodes Scholarship, Oxford University, England. There he devoted three years to his chosen field, ecology. His vacations were spent travelling throughout continental Europe. On returning to this country he completed his dissertation of the "Ecology of the Grassland Biome" and was awarded his doctorate at the University of Oklahoma in June, 1938. For three years prior to his death he taught in a neighboring institution, Black Mountain College.

The field of biology has suffered a distinct loss with the passing of Dr. Carpenter. He was a man of exemplary habits, fine ideals, a worthy friend and associate, and possessed an abundance of enthusiasm to qualify him as an excellent teacher and investigator. The demise of a capable, well trained man at the very threshold of a career full of promise is always a great misfortune and an irreparable loss, and such is strikingly the case with Dr. Carpenter. This is amply attested by the following incomplete list of his most important scientific contributions:

"Diurnal Fluctuations in Communities Adjoining the Forest Edge near Urbana, Ill." *Proc. Okla. Acad. Sci.* 14: 29-31. 1934.

"Forest Edge Birds and Exposures of Their Habitats." *Wilson Bull.* 47: 106-108. 1935.

"Fluctuations in Biotic Communities, I. Prairie-Forest Ecotone of Central Illinois." *Ecology* 16: 203-212. 1935.

"The Ecology of Marine Estuaries." *J. Anim. Ecol.* 5: 192-195. 1936.

"Fluctuations in Biotic Communities, II. Daily Fluctuations in Insect Populations in the Prairie-Forest Ecotone of North America." *C. R. XII<sup>e</sup> Congr. Int. de Zoologie, Lisbonne*, 2: 969-979. 1936.

"Quantitative Community Studies of Land Animals." *J. Anim. Ecol.* 5: 231-245. 1936.

"The Use of Sweep Net Samples in an Ecological Survey" (with J. Ford). *J. Soc. Brit. Ent. L.* 155-161. 1936.

"Fluctuations in Biotic Communities, III. Aspection in a Ravine Sere in Central Oklahoma." *Ecology* 18: 80-92. 1937.

"An Ecological Glossary." Univ. Okla. Press, 1938. ix, 309 pp.

The Academy deeply mourns his loss and extends sincerest sympathies to his bereaved parents and brothers.

Committee: F. A. WOLF  
A. S. PEARSE

The resolution was adopted by a rising vote.

With the untimely death of Scott Cary Lyon, July 23, 1942, Davidson College lost the head of its Biology Department and one of its most respected faculty members.

Dr. Lyon was born in Washington, Pa., October 20, 1884. In 1904 he received his A.B. degree at Southwestern Presbyterian University. This was followed by an A.M. degree from Tulane in 1909.

Dr. Lyon was deeply interested in Christian education, and followed his father and grandfather into the teaching profession. He served as Professor of Mathematics at Alabama Presbyterian College from 1909-1910. Moving then to Southwestern Presbyterian University, he served as Professor of Chemistry from 1910-1917, and as Professor of Chemistry and Biology, and as Dean, from 1917 to 1925. In 1926 he was awarded the degree of Doctor of Science by his Alma Mater. In the same year Dr. Lyon was elected to the Richard J. Reynolds Chair of Biology at Davidson College. He filled this post until his death in 1942.

Dr. Lyon was not primarily interested in research. His chief energies were directed toward his teaching duties. However, during his years at Southwestern he developed a considerable interest in entomology, especially in the chemotropic responses of insects. For many summers he served as Assistant at the Clarks-ville (Tenn.) Field Station of the U. S. Bureau of Entomology. He was elected president of the Tennessee Academy of Science in 1925.

As a member of the Davidson faculty Dr. Lyon was highly respected by both fellow-workers and students. In group discussions he was a man of sane and stable judgment. He exhibited a sincere and untiring interest in student problems and activities. In the classroom he developed an enviable reputation for lucid, concise and pointed teaching.

Dr. Lyon was married in 1909 to Malline Bradford, of Cedartown, Ga. He is survived by Mrs. Lyon, now of Wilmington, N. C., and by two children, Malline Bradford (Mrs. Philip Slaughter) and Capt. William Adair Lyon.

Committee: DORISSE HOWE  
MARY E. CONRAD  
E. E. BROWN

The resolution was adopted by a rising vote.

Dr. F. H. Swett, who died in his office on the Duke University campus February 10, 1943, came to North Carolina in 1930 as the first Professor of Anatomy in the Duke University Medical School. He successfully carried through the difficult assignment of organizing a new department and establishing traditions of scholarship and sound teaching. His poise and judgment made him a valuable counsellor in affairs of the School outside of his own department. His colleagues and many other friends, including a generation of medical students at Hopkins, Vanderbilt, and Duke, valued him as a courteous, generous and genial gentleman.

Dr. Swett's contributions to research in the biological sciences were largely in the field of experimental embryology. Consistently since 1921 he has published papers dealing with the subject of his major interest (regeneration following transplantation of organ rudiments). In late years he devoted much constructive thought to the problem of medical education, participating largely in deliberations on this subject by the Association of American Medical Colleges, and papers by him have appeared from time to time in the Journal of that Association. The American Association of Anatomists in 1942 recognized the merit of his scientific work and his personal charm by electing him Secretary-Treasurer of the Association. His membership in other organizations for the promotion of scholarship included Phi Beta Kappa, Gamma Alpha, Sigma Xi, American Association for the Advancement of Science, Society of Experimental Biology and Medicine, Corporation of the Woods Hole Marine Biological Laboratory, Long Island Biological Association, Society for the Study of Development and Growth, and the North Carolina Academy of Science.

Francis Huntington Swett was born in Norway, Maine, November 13, 1893, the son of Eugene and Carrie (Huntington) Swett. Following graduation from Bates College in 1916 he went to Brown University for graduate study. He received the degree of Master of Arts from Brown in 1917. After service in the army during the last World War he returned to graduate study at Yale University in 1919. Yale conferred upon him the degree of Doctor of Philosophy in Zoology in 1922. From 1922 to 1925 he was Instructor and Associate in Anatomy in Johns Hopkins Medical School, and from 1925 to 1930 was Associate Professor of Anatomy in Vanderbilt University School of Medicine. He was married July 19, 1924, to Miss Elisabeth Glen, of Baltimore, who survives him.

Dr. Swett's passing is mourned by his colleagues and associates and by his many friends throughout the country. The North Carolina Academy of Science is conscious of the loss to the nation and to North Carolina of a very able man of science, and its members wish to express sympathy to Mrs. Swett and other relatives in their bereavement.

H. S. WELLS

W. A. PERLEWEIG

W. C. GEORGE, *Chairman*

The resolution was adopted by a rising vote.

Joseph Hyde Pratt was born in Hartford, Connecticut, on February 3, 1870, and died in Chapel Hill, North Carolina, on June 2, 1942, at the age of 72 years.

He came from early colonial stock, his forbears having settled in New England about 1632. He was the son of James Church and Jennie Abby (Peck) Pratt.

He was educated in the Hartford Public High School and the Sheffield Scientific School of Yale University where he received the Ph.B. degree in 1893 and the Ph.D. degree in 1896. As an undergraduate his chief interest was in chemistry. In the summer of 1892 he spent several weeks with S. L. Penfield and J. A. Holmes studying mineral areas in western North Carolina. This experience doubtless shifted his chief interest from chemistry to mineralogy and geology.

He served as laboratory assistant in chemistry at Yale during the year 1893-1894, and as laboratory assistant in mineralogy during the years 1894-1896. He was instructor in mineralogy in the Harvard Summer School of 1895 and at Yale in 1896-1897.

Dr. Pratt came to North Carolina in 1897 as State Mineralogist, and made his home at Chapel Hill for the remainder of his life. This choice of a southern state as a permanent residence was not entirely accidental. At the outbreak of the Civil War, his father, James Church Pratt, had lived in Louisiana for a number of years and served as a Captain in the Confederate Army throughout the war. Due to economic conditions in the South, at the close of the war, he returned to Hartford and entered business as a merchant.

Dr. Pratt was State Mineralogist of North Carolina from 1897 to 1906, and State Geologist from 1906 to 1924. He was lecturer in mineralogy and economic geology at the University of North Carolina from 1899 to 1904 and professor of economic geology from 1904 to 1924. He also served as assistant field geologist to the U. S. Geological Survey from 1899 to 1910, as a member of the International Jury of Awards at the St. Louis Exposition in 1904, as director of briquetting experiments at the U. S. Geological Survey Coal Testing Plant at St. Louis in 1904-1905, as chief of the Department of Mines and Metallurgy at the Jamestown Exposition in 1907, and as special expert to the U. S. Twelfth Census on a number of minerals.

As State Mineralogist of North Carolina, his work was devoted almost entirely to mineralogy and geology, and he made many valuable contributions to geological literature. He was the discoverer or co-discoverer of four new minerals, pirssonite, wellsite, rhodolite, and mitchellite. He was strongly interested in the wide variety of gems and gem materials in North Carolina and won prizes at the Pan-American Exposition at Buffalo in 1901, and the Charleston Exposition in 1902 for his exhibits of these minerals.

In 1906 Pratt was appointed State Geologist to succeed J. A. Holmes, who had been made the first Director of the U. S. Bureau of Mines. As State Geologist, Holmes had spent much of his time laying a foundation policy for good roads, forestry, water power and conservation, and Pratt's keen mind readily grasped the importance of such things for North Carolina. He was one of the great men in conservation. He was a leader in the movement to establish a forest reservation in the Southern Appalachians and worked incessantly for the passage of the Weeks law authorizing the acquisition of land for National Forests. He organized the Southern Forestry Congress, the North Carolina Forestry

Association, Good Roads Associations, sponsored good roads days, conducted good roads institutes and sponsored fisheries and drainage conventions.

When the United States entered the war in 1917 he entered the military service of his country as a Major in the Reserve Corps of April 24, 1917, and was assigned to the 105th Regiment of Engineers, where he was promoted to Lieutenant Colonel on November 11, 1917, and Colonel on October 9, 1918. He served as Commander of the regiment and division engineer, with the 30th Division in France from July 1918 to May 1919 and was at the front on the Ypres sector, Flanders and Belgium, and the Somme offensive. He was awarded the Distinguished Service Medal in recognition of his military services.

At the close of the war he returned home with impaired health and being unable to continue his duties as State Geologist resigned the position and his professorship in the University of North Carolina in February 1924. He did not, however, give up his interest in minerals, geology, and conservation.

Dr. Pratt was vitally interested in people and their welfare and took an active part in programs for civic and social betterment. He served at one time or another as President of the North Carolina Conference for Social Service, the North Carolina Society for the Preservation of Antiquities, the North Carolina Symphony Society, the Battle Park Association, the Chapel Hill Public Recreation Committee, Chairman of the Chapel Hill Chapter of the American Red Cross, the Central Welfare Committee of Orange County, the Chapel Hill Health and Welfare Committee, and the Chapel Hill Negro Community Center Association. In 1940 he received the Annual Award as Chapel Hill's most valuable citizen.

In 1923 Yale University bestowed the honorary M. A. degree upon him. The Board of Trustees of the University of North Carolina voted to honor him at the 1942 commencement of the North Carolina State College of Agriculture and Engineering of the University with the degree of Doctor of Engineering, but his last illness prevented his being present to receive it.

Dr. Pratt was a Fellow of the Geological Society of America, the American Association for the Advancement of Science, the American Chemical Society, the National Geographical Society, the American Geographical Society, and Mineralogical Society of America, a member of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the Mining and Metallurgical Society of America, the New York Academy of Science, the North Carolina Academy of Science, and Sigma Xi.

The passing of Dr. Pratt represents a distinct loss in the fields of science and statesmanship in North Carolina and the nation. The North Carolina Academy of Science regrets the loss of a valuable member and extends its deepest sympathy to his wife, his son and other relatives.

Committee: W. F. PROUTY

R. E. COKER

J. L. STUCKEY, *Chairman*

The resolution was adopted by a rising vote.

## REPORT OF THE RESOLUTIONS COMMITTEE

The North Carolina Academy of Science wishes to express its great appreciation to the local committee on arrangements for their labor in making provisions for a pleasant and successful meeting, to Prof. C. G. Bookout for intelligent and efficient handling of press releases, and to our hosts, the President and other officials and faculty members of Duke University, for their generous courtesies and hospitality which have contributed so much to our pleasure during the meetings.

Z. P. METCALF

H. L. GRAVETTE

W. C. GEORGE, *Chairman*

The report was adopted.

## REPORT OF THE NOMINATING COMMITTEE

The Nominating Committee submits the following slate:

*President:* M. L. Braun, Catawba

*Vice-President:* Mary E. Yarborough, Meredith.

*Member of the Executive Committee:* E. H. Hall.

*Member of the Research Grant Committee:* W. E. Speas, Wake Forest.

Nominations from the floor were called for. There being none, the Secretary was instructed by vote to cast the ballot. The Secretary reported that such a ballot had been cast and the President declared the nominees elected.

A call was made for any other business. There being none, the Academy adjourned.

The membership then enjoyed a buffet supper with Duke University serving as host. The informality of the supper gave an excellent opportunity for social intercourse.

At 7:00 P.M. the evening session was called to order and W. A. Perlzweig was called upon to serve as chairman of the "Symposium on nutrition in war time."

At 8:30 P.M. Eva G. Campbell, Vice-President, took the chair and introduced R. L. Flowers, President of Duke University, who welcomed the Academy to Duke. Dr. Flowers holds a rather unique position—he is the only President of a North Carolina educational institution who is also a member of the Academy.

Vice-President Campbell responded for the Academy. She then introduced the winner of the Academy High School Award and presented the prize of \$20 to Mr. Donald Hartzog of Winston-Salem for his exhibit of photographs and photographic techniques. Robert Anderson was then presented with an award of \$20, provided by the North Carolina Forestry Association, for a competitive essay entitled "Fire In The American Forests."

Dr. Campbell then introduced H. F. Prytherch, President of the Academy, who spoke on "Vitamin Machines of Southern Seas." The address was illustrated with Kodachrome slides and moving pictures. The Academy adjourned for a social hour in the lobby of the Biology Building. Refreshment of body and acquaintanceships was enjoyed by all.

Saturday was devoted wholly to sectional meetings. These were well attended and each had an unusually good program. About 200 registered at the desk, but a review of the sectional attendance indicates that more than 300 attended the various meetings. The Psychology Section was the last to complete its program, and the Academy officially adjourned at 1:15 P.M.

The following sectional officers were elected by the respective groups:

*Botany*: Chairman, F. A. Wolf; Secretary, E. C. Cocke (45). Attendance about 40.

*Biochemistry and Physiology*: Chairman, H. W. Ferrill; Secretary, J. C. Andrews (45). Attendance about 45.

*Geology*: Chairman, W. F. Prouty; Secretary, Willard Berry (45). Attendance about 15.

*Mathematics*: no meeting.

*Physics*: Chairman, W. A. Speas; Secretary, N. Rosen (46). Attendance, about 60.

*Psychology*: Chairman, Elizabeth Duffy; Secretary, Karl Zener (45). Attendance about 35.

*Wild Life*: Chairman, J. D. Findley; Secretary, R. O. Stevens (45). Attendance about 30.

*Zoology*: Chairman, G. T. Hargitt; Secretary, Eva G. Campbell (45). Attendance about 30.

The personnel of the standing committees follows:

*Executive*: M. L. Braun, Mary E. Yarborough, Bert Cunningham, D. B. Anderson, O. J. Thies, E. H. Hall.

*Research Grants*: J. N. Couch (44), C. F. Korstian (44), J. P. Givler (45), W. E. Speas (46).

President M. L. Braun announces the following committees to serve during 1943-44.

*Auditing*: W. L. Porter, Chairman; Frazer Hood, H. E. Fulcher.

*Conservation*: J. S. Holmes, Chairman; C. H. Bostian, C. F. Korstian, R. A. Lineberry.

*High School*: M. F. Buell, Chairman; Elizabeth H. Conner, W. S. DeLoach, C. F. Dodson, J. H. Highsmith, Dorothy E. Wilson, J. S. Meares.

*Legislative*: E. W. Berry, Chairman; B. C. Burgess, H. F. Prytherch, B. W. Wells.

*Nominating*: H. F. Prytherch, Chairman; C. M. Heck, W. F. Prouty.

*Necrology*: Minnie A. Graham, Chairman; A. L. Hook, W. E. Jordon, Z. P. Metcalf, F. Louise Schaeffer.

*Potential Award*: A. D. Shaftesbury, Chairman; J. B. Bullitt, J. B. Derieux, I. E. Gray, Frazer Hood, P. J. Kramer, J. W. Lasley, Jr., G. H. Satterfield, J. L. Stuckey.

*Resolutions*: O. Stuhlman, Jr., Chairman; K. L. Barkley, W. D. Mankin.

*Secretarial and Constitution*: H. R. Totten, Chairman; H. R. Blomquist, Bert Cunningham.

*College Science Clubs*: P. M. Ginnings, Chairman; C. H. Bostian, Eva Camp-



bell, Mary Conrad, J. B. Derieux, C. F. Dodson, C. W. Edwards, Minnie A. Graham, E. H. Hall, Harvey A. Ljung, R. N. Wilson.

*Publications:* to be appointed later.

The following papers were presented during the meeting. Those marked with an x are abstracted in the Proceedings; those marked with an \* are published in full.

#### GENERAL SESSIONS

*Address of Welcome.* R. L. FLOWERS, President of Duke University  
*Presidential Address. Vitamin Machines of Southern Seas.* H. F. PRYTHERCH, President of the Academy

x*North Carolina forest products as sources of vital war materials.* E. E. RANDOLPH, State College.

*The philosophy of the scientific method* (Charts, 15 min.). Z. P. METCALF, State College.

*Balanced diet selecting apparatus, U. S. patent 2,314,387.* VICTORIA CARLSSON, Woman's College, University of N. C.

*Agar resources of the Atlantic coast.* HAROLD J. HUMM, Duke Marine Station.

*Symposium on health and the war.* DR. MILTON J. ROSENAU, Presiding.

*Venereal diseases.* DR. WM. L. FLEMING, Professor of Syphilology, School Public Health, University of N. C.

*Planning for the health of the community in time of war and peace.* DR. CARL V. REYNOLDS, Secretary and State Health Officer, N. C. State Board of Health, Raleigh.

*Socialized medicine.* DR. WINGATE H. JOHNSON, Private Diagnostic Clinic, Bowman Gray School of Medicine of Wake Forest College, Winston-Salem.

*Public health and war.* DR. WINFIELD KENNEDY SHARP, JR., Surgeon, U. S. Public Health Service and District Director of Interstate Sanitary District Number 2, Washington, D. C.

*Our substitute for Empire.* SAMUEL T. EMORY, University of N. C.

x*The measurement of peripheral visual acuity.* FRANK N. LOW, University of N. C.

x*An anomalous embryo—A report and a morphogenetic interpretation.* W. C. GEORGE, University of N. C.

*The ultracentrifuge in virus research.* JOSEPH W. BEARD, Duke University.

*Ultracentrifugal isolation and purification of Influenza Virus A.* ALTON R. TAYLOR, Duke University.

*Electron micrography of viruses.* D. GORDON SHARP, Duke University.

*Symposium on nutrition in war time.* W. A. PERLZWEIG, Presiding.

*Nutrition surveys in North Carolina.* F. D. MILAM, International Health Division, Rockefeller Foundation, Director, Cooperative North Carolina Nutrition Survey.

*An adequate diet under a rationing system.* JAMES C. ANDREWS, Professor of Biological Chemistry, University of North Carolina.

*Bread in war time.* W. J. DANN, Associate Professor of Nutrition, Duke University.

## BIOCHEMISTRY AND PHYSIOLOGY

*Enzymic debridement in the local treatment of burns.* GERALD R. COOPER AND JOSEPH W. BEARD, Duke University School of Medicine.

*Further studies on serine injury.* W. H. FISHMAN AND C. ARTOM, Bowman Gray Medical School.

*The effect of small doses of ethyl alcohol on the white rat.* H. WARD FERRILL, University of N. C.

*Studies on substances interfering with quinine estimation (Lantern).* G. C. KYKER AND DOROTHY PLONK, University of North Carolina.

*Water soluble vitamins and growth of the albino rat (Lantern, 15 min.).* W. J. DANN, Duke University.

*Equipment for the study of chronic exposure to toxic gases (Lantern, 10 min.).* A. T. MILLER, JR., University of N. C.

*The relation of the diet to liver phospholipids in rats of two age groups.* C. ARTOM AND W. H. FISHMAN, Bowman Gray Medical School.

*The effect of liver damage and hemorrhagic anemia on the urinary excretion of quinine.* W. E. CORNATZER AND J. C. ANDREWS, University of N. C.

*Some chemical and biological aspects of protein denaturation.* HANS NEURATH, JOHN O. ERICKSON, FRANK W. PUTNAM AND ELLIOT VOLKIN, Duke University School of Medicine.

*The physico-chemical properties of native denatured, and regenerated bovine albumin.* FRANK W. PUTNAM, JOHN O. ERICKSON, ELLIOT VOLKIN, AND HANS NEURATH, Duke University School of Medicine.

*The immunological properties of native and regenerated serum albumin.* JOHN O. ERICKSON, DONALD S. MARTIN, FRANK W. PUTNAM AND HANS NEURATH, Duke University School of Medicine.

*XA factor in yeast other than vitamin B<sub>12</sub> which stimulates hemoglobin production in the dog.* SUSAN G. SMITH, HAROLD HAWFIELD, ROBERT CURRY, RICHARD CONNAR AND JOHN COLLINS, Duke University.

## BOTANY SECTION

*Some remarks on the idea of chromosome pairing.* H. W. JENSEN, Wilson Jr. College.

*The development of primary vessels in Ipomoea batatas L. (Lantern, 12 min.).* MARTHA C. LIVINGSTON AND RUTH M. ADDOMS, Duke University.

*The marine algae of Puerto Rico (Lantern, 15 min.).* H. L. BLUMQUIST, Duke University.

*A new golden-brown alga—Phaeosphaera perforata.* L. A. WHITFORD, N. C. State.

*The comparative effect of ground and crown fire on the composition of a loblolly pine community (Lantern, 10 min.).* HENRY J. OOSTING, Duke University.

*The importance of non-osmotic forces in the absorption of water by plant cells (Lantern, 12 min.).* PAUL J. KRAMER, Duke University.

*Control of starchy contaminations in sweet corn by the use of the "gamete" gene.* H. S. PERRY, Duke University.

*Heterochromosomes in species of Ilex and the lack of them in species of Thalictrum* (Lantern, 15 min.). H. W. JENSEN, Wilson Jr. College.

*xThe rediscovery of Nadsonia, a yeast with heterogamic conjugation.* J. N. COUCH, University of North Carolina.

#### GEOLOGY SECTION

*\*The strategic mineral situation in the Southeastern United States* (15 min.). W. F. PROUTY, University of N. C.

*xExogyra costata zone in Horry County, South Carolina* (Lantern, 15 min.). WILLARD BERRY, Duke University.

*The structure and stratigraphy of Cove Mountain area, Virginia* (15 min.). J. W. HUDDLE, University of N. C.

*Mineral industry in North Carolina in 1942* (15 min.). J. L. STUCKEY, State.

*xRecent wells near Elizabeth City, North Carolina.* WILLARD BERRY, Duke University.

*New mineral development in the Eastern Piedmont* (15 min.). J. L. STUCKEY AND W. A. WHITE, State Geological Survey.

*xBlythe Bay: a record of changing ocean levels.* B. W. WELLS.

#### PHYSICS SECTION

*Greetings from the Southeastern Section of the American Physical Society.* C. W. EDWARDS, Physics Department, Duke University.

*Light and heavy mesons in the cosmic radiation.* L. W. NORDHEIM, Duke University.

*Physics in war time.* ROBERT B. LINDSAY, Brown University.

*The near ultraviolet absorption spectra of O- and m-Chlorofluorobenzene.* (Lantern, 12 min.). ARNOLD BASS, Duke University.

*Air mass analysis in meteorology.* F. W. CONSTANT, Duke University.

*Elementary solutions of the Schrödinger equation.* NATHAN ROSEN, University North Carolina.

*A direct current amplifier.* J. C. MOUZON, Duke University.

*Panel discussion on the war and the physicists.* DR. RUARK,† University of North Carolina.

† In Dr. Ruark's absence, due to war work, Dr. O. Stuhlman was asked to act for him.

#### PSYCHOLOGY SECTION

*xDepersonalization—its significance for psychology and psychopathology.* ERWIN STREAS, Black Mountain College.

*xThe effect of past experience upon limens of visual form perception.* (Lantern, 15 min.). WILLIAM BEVAN AND KARL ZENER, Duke University.

*Note:* For those interested, a demonstration of conditioned salivary secretion in the dog will be conducted by Karl Zener.

- The dependence of experimental "neurosis" in the rat upon some characteristics of blood composition.* OLIVER L. LACEY, Woman's College, University of North Carolina.
- x*The writing and drawing of psychotic individuals after electrically induced convulsions.* EDWARD STAINBROOK AND HANS LOWENBACH, Duke Univ. School of Medicine.
- An experiment in third grade arithmetic.* WILLIAM BROWNELL AND HAROLD MOSEB, Duke University.
- x*The thyroid gland and the electroencephalogram of the rat.* FRANK DAVIS, JR., AND BERT CUNNINGHAM, Duke University.
- x*Further studies of imitational learning in rats.* A. G. BAYROFF, University of N. C.
- Psychological research in progress at Davidson.* FRAZER HOOD, Davidson College.
- x*Values students received from study of emotions.* KEY L. BARKLEY, Woman's College U. N. C.
- x*Detachment of conditioned emotional reactions.* ENGLISH BAGBY, University of N. C.
- x*Organization in memorizing.* J. F. DASHIELL, University of N. C.
- Multiple bi-serial prediction.* ROBERT J. WHERRY, University of N. C.
- x*The electroencephalogram as an aid to diagnosis of behavior problems.* MARGARET HENDERSON.
- x*Maximal weighting of qualitative categories.* ROBERT J. WHERRY.

## WILDLIFE SECTION

- x*Farm ponds for fish.* VERNE E. DAVISON, U. S. Soil Conservation Service, Spartanburg, S. C.
- x*The status of the wood duck in North Carolina.* JAMES L. STEPHENS, Lumberton, N. C.
- x*Notes on the food habits of the bobwhite quail in North Carolina.* WILLIAM M. LEWIS, State College, Raleigh.
- \**Basic wildlife conservation.* R. O. STEVENS, State College.
- x*The present status of the beaver in North Carolina.* C. S. BRIMLEY, Raleigh, N. C.
- x*Notes on the eighth North American Wildlife Conference.* WILLIS KING, Raleigh, N. C.

## ZOOLOGY SECTION

- x*The status of the modern Amphibia among the tetrapoda* (Lantern, 15 min.). F. GAYNOR EVANS, Duke University.
- x*The cestodes of North Carolina poultry with remarks on the life history of *Raillietina tetragona*.* REINARD HARKEMA, State College.
- A new case of nuclear extrusion* (Lantern, 12 min.). MYCHYLE W. JOHNSON, Duke University.

*The role of the roof rat (Rattus rattus alexandrinus) as a reservoir of murine typhus in the United States.* STERLING BRACKETT AND ALBERT J. BECKMANN, University of N. C.

*xThe lymph system as main factor in regeneration of oligochaetes* (Lantern, 15 min.). EMIL LIEBMANN, Duke University.

*xEffects of burning-over and raking-off litter on certain soil animals in the Duke forest* (Lantern, 15 min.). A. S. PEARSE, Duke University.

*Rare cyclopoid copepods from wells in North Carolina.* H. C. YEATMAN AND R. E. COKER, University of N. C.

*The normal changes in weight and water content during the life cycle of the wood-eating beetle, Passalus cornutus Fabricius* (Lantern, 10 min.). I. E. GRAY, Duke University.

*The birds of Charlotte and Mecklenburg County, North Carolina.* (To be read by title). ELIZABETH B. CLARKSON.

#### HIGH SCHOOL SCIENCE TEACHERS

*The place of science clubs in education.* M. F. BUELL, State.

*The eighth and ninth grade courses in science.* J. O. TAYLOR, Raleigh.

*Ornithology for high school students.* ROXIE C. SIMPSON, State Museum.

*Round table—Collection and preservation of laboratory materials* (limit, 30 min.).

*Round table—Pre-induction courses in High School.*

#### NORTH CAROLINA SECTION OF THE AMERICAN CHEMICAL SOCIETY

*The dielectric constants of some liquid mixtures.* A. J. WEITH, JR., AND MARCUS E. HOBBS, Duke University.

*Reactions of esters with bases and Grignard reagents.* C. R. HAUSER, J. C. SHIVERS AND P. S. SKELL, Duke University.

*Studies of mono and di-substituted alkyl and cycloalkyl ketenes.* CARL M. HILL, Agricultural and Technical College.

*The magnetic moments of some nickel and iron complex ions.* W. C. VOSBURGH, C. D. RUSSELL, AND B. WERBEL, Duke University.

#### Abstracts:

*North Carolina Forests as Sources of Vital War Materials.* E. E. RANDOLPH.

The United States Forest Service classes about one-third of the area of North Carolina as forest land. Some of this land is burnt over land, some is cut over land, and some is sparsely stocked.

In the Coastal Plain grow the pines, gums, cypress, cedar, oaks, poplar, ash, persimmon, and dogwood. The wood is used for lumber, poles, piles, cross ties, veneer, furniture, crates, baskets, pulpwood, shipbuilding and the resin for turpentine stills. In the Piedmont area grow oaks, hickory, poplar, ash, elm, sycamore, dogwood, cedar, and pines. This area contains the great furniture, tobacco, textile, and many other important industries. Much lumber is therefore used for furniture, crates, cooperage, shuttle blocks, picker sticks, veneer, and building, and considerable pulp wood is marketed. In the Mountain

area grow the chestnut, oaks, poplar, hickory, maple, walnut, cherry, ash, white and other pines. This wood is used largely for pulpwood, lumber, and furniture material.

For some years the state has had one of the largest military posts in the country. Within the past two years this post has been greatly enlarged and a number of other military bases have been built. Heavy demands have therefore been made on our forests for them and for shipbuilding uses.

In addition to supplying lumber for the physical needs of the army, the forests have contributed to the war effort through products obtained by chemical means and through chemical conversion products. A few plants still produce naval stores by steam distillation of the resin and trunks and stumps of pines. Sufficient tannin is obtained from chestnut, oak, and hemlock to supply the needs of tanneries of the state which tan about twenty million dollars worth of leather a year. Considerable wood is supplied to a large industry in a neighboring state which makes of part of it pulp and a part of it is distilled for acetic acid, alcohol, and acetone. All of these are then used to convert the cellulose pulp into plastic, moving picture films, and rayon. The plastic is used in airplane building, the films are used in the intelligence service, and the rayon is used for fabric for tires. The state produces much veneer and plywood. These materials are used considerably for airplane construction.

The state has four large pulp and paper mills which use between four and five thousand cords of wood daily for making all kinds of paper, containers, and shipping box board. Our forests also furnish pulpwood to nearby mills in adjoining states. Much of this material is required for military use.

The pulp mills of the state and country supply special pulp for practically all of the chemical conversion products of cellulose. Wood is the best general source of cellulose. It is plentiful, available, easily processed, and supplies the most cellulose per unit volume of the various sources available.

Plastics are made from cellulose, natural resins, and synthetic resins. Those that are made from cellulose are esters, ethers, and mixed esters obtained from wood pulp. Thousands of tons of plastics are used in building the nose and pilot house and other parts of airplanes.

Certain cellulose esters can be dissolved in suitable solvents and made into varnish, lacquers, and vehicles for paints. These materials form weatherproof protective coatings. They are sufficiently elastic to form a permanently adhesive coating. Some of these materials are suitable for weatherproofing tent cloth so that it may be rolled up and still retain its water repellent properties.

Cellophane made from cellulose ester can be coated so as to be moisture proof. Moisture, dust, and bacteria protective materials are necessary in army service.

Nitrocellulose is one of the chief explosives used in military action. It is the chief propellant used in guns. In making this explosive the operator does not destroy the fibrous form of the cellulose. However, nitrocellulose in the fibrous form is too violent in its detonation to be used as a propellant in guns. The rate of its burning is retarded by gelatinizing the material and then it is forced through suitable dies into short perforated rods. Nitrocellulose is also a con-

stituent of dynamite and of cordite. Familiar names for nitrocellulose are gun cotton and smokeless powder. Wood pulp is the raw material for much of this important explosive.

Cellulose from wood converted by chemical processes into different forms, therefore, serves important purposes in the war for high explosives, picture films, paper, shipping containers, fabrics for tires for motor vehicles and airplanes, parachutes, plastics, adhesives, and protective coatings.

*The Measurement of Peripheral Visual Acuity.* F. N. Low.

Peripheral visual acuity (or efficiency) was measured by use of Landolt broken circles varying in size from .5 mm. to 10 mm. mounted on a 25 cm. perimeter. Illumination was kept constant with a built-on illuminator, the light from a 60 w. Mazda daylight lamp 35 cm. from the test object being incident at 45°. Surroundings and operator were blacked out. The test object was revealed successively in any of 4 possible positions corresponding to points of the compass (N, S, E, W), the subject signaling the position with the eye fixed forward. Four consecutive successful identifications were necessary for a score. Nine points on each eye, 30, 60, and 90 degrees from the line of vision, were tested, the smallest circle successfully identified being scored. One hundred subjects selected at random were tested to determine the norm. The average of all scores was arbitrarily chosen as 100%. On this basis 87 males scored 102% and 13 females 91%. The best subject scored 364% and the worst 43%. This acuity was found to be an independent visual factor not correlating accurately with age, sex, central acuity, or color vision. With central acuity there was a positive correlation of .39, thus yielding almost no practical reciprocal predictive value. Although the youngest group was the best, the peripheral acuity did not decline with age. Eight color blind individuals scored an average of 92%. The test showed a .91 reliability.

Of the original group of 100, 30 were males aged 18-27 yrs. inclusive, had normal or better central vision, normal color vision, and no astigmatism. Their average score was 115%, the best scoring 210% and the worst 52%. These latter two represented the 2nd and 99th in degree of peripheral acuity of the original group of 100.

A shortened version of the test taking 12-14 minutes (as compared to 40-60 minutes for the original) was run on 113 subjects and repeated in from 6-8 wks. The second scores showed an average of 6% improvement. Twenty of the original 100 were retested and showed an average of 15.8% improvement. The improvement was roughly proportional to the amount of time taken by the test. In two test groups out of three the second eye tested better than the first.

This investigation has revealed great spontaneous variability in peripheral visual acuity, always without the individual's awareness. It shows such acuity to be an independent visual factor. The evidence indicates that peripheral visual acuity can be trained.

*An Anomalous Embryo—a Report and a Morphogenetic Interpretation.* W. C. GEORGE.

A pig fetus of about 7 mm. length without any observed external abnormalities has a double notochord from the level of the tenth spinal nerve cephalically. In addition to the anomalous notochord the fetus has paired Rathke's pouches, paired infundibula, paired floor plates in the region of the bifid notochord, a median thickening of nerve tissue between the floor plates with median nerve trunks extending ventrally into the connective tissue of the roof of the pharynx.

The specimen is considered to be a case of incomplete twinning evident only in its internal structure; the median nerves are looked upon as combined right and left cranial nerves representing cranial nerves 3, 4, 5, 6 and 7 from adjacent incomplete halves of two individuals forming a single composite individual.

Morphogenetic interpretation: a retardation of development at a critical moment causes doubling of a growing point (Stockard). In this case it is assumed that a retardation occurred at the critical juncture at the outgrowth of the head process from the primitive knot resulting in paired notochords cephalad to the primitive knot. Since presumptive notochord induces neural plate formation (Bautzmann et al.), the paired notochords in this case induced two floor plates and apparently two physiological axes in the cephalic portion of the embryo. In consequence of the two physiological axes paired pituitary glands developed, perhaps through the operation of organizers or possibly of mechanical factors. The conditions in this fetus seem to justify application to the mammals of those conclusions reached by experimental embryologists concerning the importance of the notochord in determining the physiological axes of the embryo in amphibia.

Cases of paired lower portions of the spinal chord are on record among adult human beings. There is no apparent reason why persons with similar paired organs and partially paired brains as in this fetus might not be born and live. The question arises as to the psychological difficulties and personality problems that might occur in such an individual.

*A Factor in Yeast Other than Vitamin B<sub>6</sub> Which Stimulates Hemoglobin Production in the Dog.* SUSAN G. SMITH, HAROLD HAWFIELD, ROBERT CURAY, RICHARD CONNAR and JOHN COLLINS.

Dogs were placed on a synthetic B-complex free basic diet and given seven synthetic B-complex factors (B, riboflavin, nicotinic acid, pantothenic acid, inositol, choline and para-aminobenzoic acid) but no B<sub>6</sub>. Under these conditions the dogs failed to gain weight and developed a hypochromic, microcytic anemia typical of B<sub>6</sub> deficiency previously described in the dog and in the pig. When synthetic B<sub>6</sub> alone was added to the diet there was a prompt and dramatic rise in the hemoglobin which then returned gradually to the accepted normal value of 14 grams. If brewer's yeast is then given there is an additional gradual increase to values around 20 grams. With this increase in hemoglobin there was an increase in weight, vitality, and everything indicating improved general health of the animal.



The positive control dogs (receiving yeast at a level of 10 per cent throughout the experiment) maintained an average hemoglobin value of 18 grams. The higher value in the treated dogs probably indicates a typical rebound of an anemic animal.

*The Rediscovery of Nadsonia, a Yeast with Heterogamic Conjugation.* J. N. COUCH

The yeast genus *Nadsonia*, comprising two species and first described growing in the sap of trees in Russia in 1911, is reported for the first time since its original discovery. One species was found in the exuding sap of a birch stump near Chapel Hill. My observations on its life cycle confirm in the main those of the original authors, Nadson and Kotonokine.

*Recent Wells near Elizabeth City, North Carolina.* WILLARD BERRY.

Three wells drilled last year at the Air Base near Elizabeth City penetrated to depths of 65 feet, 30 feet, and 73 feet. The beds penetrated were fine to medium, and fine sand, and some sandy shale. Shell fragments were present in 2 of the wells with a few *Bryozoa* fragments, and *Echinoid* spines. In the lowest sample of the first well there was considerable carbonaceous material (buried swamp debris?). Compared with previously described wells from this area these wells all end in the Pleistocene.

*Exogyra costata Zone in Horry County, South Carolina.* WILLARD BERRY.

Upper Cretaceous has been reported from seven localities in Horry County, northeast corner of South Carolina. *Exogyra costata* Say has been reported from two localities and *Cassidulus emmonsii* Stephenson from one. No fossils are reported from the other localities. During the deepening of the Intercoastal Waterway, about 1939, from Little River towards Myrtle Beach large quantities of gray sandy micaceous shale were spread on the spoil piles. This shale is identified with the *Exogyra costata* zone of the Pee Dee (upper Cretaceous). Identified from this spoil are *Cassidulus emmonsii* Stephenson, *C. subquadratus* Conrad, *C. aequoreus* Morton, *C. sp.*; internal casts of *Cucullaea* (?); *Exogyra costata* Say, *E. cancellata* Stephenson; *Eutrophoceras dekayi* (Morton); *Nautilus* (?) *bryani* Gabb; and *Sphenodiscus lobatus* (Tuomey) Meek. These are all from the *Exogyra costata* zone elsewhere and should therefore indicate the presence of the zone in the extreme eastern part of South Carolina. At this locality the upper Cretaceous sediments lie some 8 to 10 feet below the tide and are overlain apparently by a thin layer of questionable and a somewhat thicker layer of definite Pamlico Pleistocene.

*Blythe Bay: A Record of Changing Ocean Levels.* B. W. WELLS.

Blythe Bay is one of the problematic Carolina Bays located in the suburbs of Wilmington, N. C., southeast of the city. The northwest end of it is reached by road and lies one mile due east of the south end of Greenfield Lake. At this end a high sand hill has moved on to the Bay end, sharply truncating it.

This Bay, lying on the Talbot terrace less than a third of a mile from the old

Pamlico sea (sound) shore line, has a peat deposit in its southeastern half which reaches a maximum thickness of 5 ft. 6 in. This deposit is buried under 7 ft. of plastic clay silt and fine sand, a sedimentation which could have occurred only by a reestablishment of a connection (tidal estuary) with sound water made possible by a reelevation of the sea level. The delta-like structure within the Bay was built by the ingressive water of this estuary established on the east side.

The data indicate the Bay was formed following the recession of the Talbot sea but of more interest it tells the story of a temporary rise of that sea, a sea level change which apparently has not been recognized by students of the late Pleistocene.

*Depersonalization—Its Significance for Psychology and Psychopathology.* ERWIN W. STRAUS.

Patients suffering from depersonalization find themselves in a deeply altered world; in experiencing and describing the change they have undergone, they point at the same time to the former state with which the new one is so painfully contrasted. To the loss of feeling corresponds the loss of reality. Reality, then, is not primarily experienced as a quality adhering to things or to their relations but as characterizing a specific kind of communication between ourselves and the world. The reality of the world and the reality of our own existence are developed in the communication of sensory experience at the same time. Each determines the other. In the single act of seeing I experience at the same time things *and* myself, both in communication. Through every sense we are in specific communication with the world. In every modality the world appears in another perspective of space, time, thingness, etc. In every modality also we experience our own bodily existence in another way. One theme runs through the many different modalities. On the side of objects: the world. On the side of the subject: myself. The ego-world relation is constant and continuous, unfolding into a variety of aspects and the multitude of experiences. Unification and separation are the basic forms of the ego-world relation; the senses primarily serve them. In regard to the subject, we speak about unifying and separating; in regard to the object, about attracting and threatening; in regard to communication, about seeking and fleeing. The subject of sensory communication therefore is not to be understood as a nervous system nor as an impersonal consciousness, but as a personal living being in a state of becoming and essentially mobile. Disturbance of communication changes the aspect of things; and changes also the structure of space and time. Depersonalization invites us: (1) to rediscover, to analyze and to describe the nature of sensory communication, and of the physiognomical world; (2) to revise accordingly the principles of psychology; (3) to inquire how our understanding of perceiving, thinking, etc., will be changed if we note and acknowledge that communication is a basic experience. To this we may add three psychopathological problems: (1) research into the different kinds of disturbances of sympathetic relations, as phobias, obsessions, hallucinations; (2) the clinical classification of deper-

sonalization as psychasthenic, depressive, schizophrenic; (3) the relation of depersonalization to schizophrenia. Without claiming that depersonalization is the central symptom of schizophrenia, yet it may well help to order the chaotic varieties of schizophrenic symptoms in relating them all to a primary disturbance of sympathetic communications.

*The Effect of Past Experience upon Limens of Visual Form Perception.* WILLIAM BEVAN, JR., and KARL ZENER.

The effect of past experience upon the threshold of visual form perception was investigated with a group of twelve students in an artificially lighted room. Simple, relatively nonsense, designs were projected on a screen and gradually increased in illumination until the subject first reported seeing something. The design was withdrawn and the subject reproduced his perception in a drawing. The procedure of gradually increasing the illumination of the projected image, with reports and drawings of each change in perception, was continued until the design was accurately reproduced.

An initial control period was followed by two training sessions of an hour each on consecutive days. In all, 232 exposures were made, certain cards being presented two times, others eight and forty-eight times. The figures were shown for two seconds at a supraliminal level of illumination. In a final control session the original liminal procedure was resumed and thresholds obtained for cards which had previously been seen once, three, nine, and forty-nine times, and also for a set of new cards.

Limens were calculated for the first perception, the first partially accurate, and the first complete perception. For all three types there was a lowering for the unfamiliar cards in the test sessions from that in the control (general transfer effect). There was also a further progressive lowering for the designs which had previously been presented. This effect of past experience with specific designs showed a marked inverse acceleration with increasing amounts of practice. Other findings were presented and theoretical and practical implications discussed.

*Writing and Drawing of Psychotic Individuals after Electrically Induced Convulsions.* EDWARD STAINBROOK and HANS LÖWENBACH.

Writing is a complex function which may be analyzed at various levels of integration and which provides a permanent record of expressive activity. Patients undergoing convulsive therapy were asked to write their names or simple sentences both before and at various intervals after electrically induced convulsions. For the additional study of perceptual and organizational functions depending more exactly upon a controlled external situation, these patients were asked also to reproduce some of Wertheimer's original gestalt figures under the same experimental conditions as prevailed for the writing.

The first letters of writing after convulsion may give evidence of tremor and motor incoordination, but all the characteristics of the individual's ordinary handwriting were seen, from the earliest performance onward, both in the formal aspects of the letters and in the general manner of writing.

The deficit for recent memory was demonstrated by the frequent reversion to names apparently associated with childhood or adolescence, the diminutive form of the name or a phonetically simpler spelling. Married women frequently wrote their maiden name.

At a low level of recovery the patient perseverates, that is, uncritically repeats letters or groups of letters once or several times in the course of writing his name or a sentence.

Perceptual organization and reproduction of a figure constricts the field of writing movement. This is evidenced by the fact that spontaneous early post-convulsive writing is expansive and space-filling while copying a model during the same level of recovery may elicit a "closing in" reaction.

Drawings made from models of complex figures which are reproduced as wholes by patients in the pre-shock state were characteristically disrupted at various levels of post-convulsive recovery. Even the earliest attempts at copying the Wertheimer designs were reactions to the whole figure, a simple loop standing for each element in the model. Angularity was the next feature to be represented, then the units of the figure were slowly brought into their proper spatial orientation and, finally, near the end of the post-convulsive recovery period the parts of the figure were joined together to make the gestalt.

It appears that an orderly and consistently occurring neurologic pattern-sequence of post-convulsive recovery may be seen in the motor functions of writing and drawing.

*The Thyroid Gland and the Electroencephalogram of the Rat.* FRANK DAVIS, JR., and BERT CUNNINGHAM.

The purpose of the experiment was to observe any correlation that may exist between the degree of thyroid function and electroencephalogram (E.E.G.) frequency. A group of eight rats was used, and each rat was taken through the following series of conditions, in the order named: (1) normal, (2) hyperthyroid, (3) normal, (4) hypothyroid, (5) normal (by medication). E.E.G.'s taken in each of the five steps showed frequencies as follows: (1) approximately 30 per second frequency in normal rats (steps 1, 3, and 5); (2) 35 to 45 per second frequencies in hyperthyroid rats; (3) 20 to 25 per second frequencies in hypothyroid rats. Since there was an increase in frequency in hyperthyroid rats, and a decrease in hypothyroid rats, and since normal frequency returned after hyperthyroidization and with thyroid medication after thyroidectomy, it was assumed that there is a direct relationship between E.E.G. frequency and degree of thyroid function. This is in harmony with similar work on humans, in which it was found that there is a high degree of correlation between E.E.G. frequency and metabolic rate.

*Further Studies of Imitational Learning in Rats.* A. G. BAYROFF and KATHLEEN LARD.

In an exploratory experiment described at the 1941 meetings of the Academy, it was found that rats can learn to follow trained rats in a two-choice situation. However, there was the possibility that the rats had been exhibiting spatial

and other hypotheses rather than a habit of following the lead rat. Other experiments were performed using escape from under water and hunger-food as motives. In the latest experiment, done by Miss Lard, the rats seem to be following the lead rats and not exhibiting pre-solution hypotheses.

*Values Received from the Study of Emotions.* KEY L. BARKLEY.

The purpose of the study was to discover the values which students say they get out of psychology. In order not to make it too broad, the study was limited to the topic of emotions.

The subjects were 226 students in elementary psychology. Forty-eight of them were in a year course with laboratory work in accompaniment; the others took a one semester lecture course.

The students in the year course were asked to write an essay on the topic, "The Values I Have Received from the Study of Emotions." The experimenter took these essays and made a check list on which was given in the students' own words all the items listed as values received. The group in the year course marked the check list in two ways: first, to indicate the items they thought they had stated in their essays as values received; secondly, to indicate all the values they believed they had received, whether or not stated in their essays. The other students marked the check list to show all the values they had received. Space was provided for the students to write in items not given in the check list. There were few such write-ins.

Certain findings are reasonably clear. The students indicated they had received many values from the study of emotions; the majority said they had received a large number of benefits. Items connected with personal adjustment were emphasized more than theoretical items. Some students indicated that they had received very little from the study of emotions.

It may be concluded that students say they have received many benefits from the study of emotions, but that many of the stated values may be simply verbalizations not accompanied by personality changes.

*The Detachment of Conditioned Fear Reactions.* ENGLISH BAGBY.

In attempts to establish experimentally the relative effectiveness of various methods of securing the detachment of conditioned fear reactions, important considerations have been very generally neglected.

In the first place, a "fear" type of conduct, without the usual smooth muscular and glandular processes, may be displayed as an adjustive device. Such conduct may appear in young children when they are "displaced in the affection of their parents" by the arrival of babies in the family (Alfred Adler). In an observed instance, a more or less deliberately feigned fear of the dark was employed by a child to prevent the re-marriage of his widowed mother.

In the second place, an episode which serves to establish a conditioned fear reaction in the simplest known way may also serve to create a fear (worry) mood. The thought-elements of this mood may in turn, by a verbal form of conditioning, reinforce the effects of the simpler conditioning process. The

resulting reaction is more than usually persistent. The most effective detachment technique—which consists in aiding the patient to assimilate the worry problem—is effective only when promptly used. Under these conditions the conditioned reaction is not reinforced.

Finally, the memory of the episode connected with the conditioning of a fear-reaction may be repressed. A phobia thus arises. Phobias do not gradually “wane” and do not yield to the usual methods of detachment and, in clinical experience, detachment involves securing a recall of the conditioning episode and often the use of certain supplementary measures.

*An Organizing Procedure in Rote Memorizing.* JOHN F. DASHIELL.

College students were given serial lists of 14 monosyllabic words to be memorized, the lists being differently constructed. The instructions emphasized only the number to be recalled, not their order. But record was kept by E of the order of the recalls. Where the word-lists permitted, eight of the nine subjects showed measurable tendencies to re-group the words in sequences that represented certain separate thought-contexts. The organizational emphasis in interpreting memory is thus given support; but the associational emphasis must be recognized as supplementary.

*The Use of the Electroencephalogram in the Study of Behavior Problem Children.*

MARGARET HENDERSON.

A comparison of brain wave records from normal children and from children classified as behavior problems indicated a significant difference between the groups, both in the number of slow waves (5–8/sec.) present, and in the abnormal brain activity induced by hyperventilation. When an attempt was made to modify the physiological processes of the cortex through the use of certain drugs, it was found that although there resulted an improvement in the behavior of the problem children, there was no significant reduction in the amount of EEG abnormality. Possible explanations for this are offered and further lines of investigation of the relationship are suggested.

*Maximal Weighting of Qualitative Categories.* ROBERT J. WHERRY.

A derivation is given for a frequently used but often criticized method of assigning numerical scores to qualitative categories of a non-metricized continuum. It is demonstrated that weights assigned in this manner do yield maximum prediction of a selected criterion. A method for priming these scores for use with IBM punched card equipment is presented. The meaning of intercorrelation among variables scored in this manner is discussed together with a consideration of the result obtained by using these intercorrelations to obtain regression weights for multiple prediction.

*Farm Ponds for Fish.* VERNE E. DAVISON.

The paper presents an agricultural concept of fishponds as a land-use measure for the benefit of the farm family and their friends. Principles of pond manage-

ment are discussed, emphasizing five features of construction and three steps in management which together make a simple chain assuring successful fishing. The small farm pond is considered as a separate problem from the management of streams and larger lakes. Greater detail is contained in an illustrated Farmer's Bulletin No. 1938, "Fish for Food from Farm Ponds," May 1943, by the same author and J. A. Johnson.

*The Status of the Wood Duck in North Carolina.* JAMES L. STEPHENS.

The wood duck population decreased in North Carolina from 1930 to 1941. Water is the most important factor in the ecology of the wood duck. If there is plenty of surface water, ducks will not become so concentrated during migration; predation will not be so great, and the wintering population will be greater than if there is little surface water. Drainage of areas to control mosquitoes and give work to unemployed is responsible for much of the loss in surface water.

The population has increased since 1941 because of changes in natural conditions, the war, and the increase in farm fish ponds.

The wood duck eats a variety of foods which are common in North Carolina. The ratio of males to females is almost one to four. Because the male is more brightly colored, he is most often killed by hunters and predators.

The war has caused restrictions on travel and on hunting. Surface water has increased because of heavy rainfall during the winter of 1942-43. The United States Department of Agriculture's farm fish pond program will provide nesting and feeding areas for wood ducks.

*Notes on the Food Habits of the Bobwhite Quail in North Carolina.* WILLIAM M. LEWIS.

One hundred and forty-one quail crops were examined and the results tabulated. Five North Carolina areas were represented as follows: thirty-two crops came from the Northern Coastal Area, ten from the Southern Coastal Area, ten from the Sandhills Area, seventy-nine from the Piedmont, and twelve from the Mountain Area.

Each food item was evaluated on the basis of its per cent of the total volume of the crops of any particular area, and the per cent of times it occurred in the total number of possibilities for the area. Foods which had a high per cent occurrence and a high per cent volume were considered as the important ones. Unless otherwise stated, when a plant is listed the seeds or fruits of the plant are the parts utilized by the quail.

The most important winter foods of the Northern Coastal Area were pokeweed (*Phytolacca americana*) and soybean (*Soja max*). Pokeweed made up 39 per cent of the total volume and soybean made up 26 per cent. Sweet gum, corn, gallberry, bullgrass and 35 other items were of lesser importance.

In the Southern Coastal Area cowpeas (*Vigna sinensis*) and bullgrass (*Paspalum boscianum*) ranked first among the different foods taken in December. Cowpeas made up 60 per cent of the total volume and bullgrass 18 per cent. Milk pea, beggarweed, beggarweed, corn, and animal matter composed the balance of the measurable volume. Eleven other plants occurred as traces.

Korean lespedeza (*Lespedeza stipulacea*), common lespedeza (*L. striata*), and cowpeas (*Vigna* spp.) were outstanding foods in the Sandhill Area. Korean lespedeza comprised 18 per cent of the total volume, cowpeas 14 per cent, and common lespedeza 11 per cent. Green vegetation, acorns, poison oak, other lespedezas, crab grass, bullgrass, animal matter (insects, spiders, and snails), ragweeds, bramble, and partridge peas were of lesser importance. Nineteen other plants occurred in very small amounts.

In the Piedmont, Korean lespedeza constituted 43 per cent of the total volume. Common lespedeza, cowpeas, wild fruits, rye, green vegetation, acorns, ragweed, beggarweed, and animal matter were other important food items. Thirty-six other plants were found in small amounts.

Korean lespedeza, partridge peas, animal matter, and corn made up all of the measurable volume of the crops of the Mountain Area. Six other plants occurred in small amounts.

*The Present Status of the Beaver in North Carolina.* C. S. BRIMLEY.

Type specimens of *Castor canadensis carolinensis* Rhoads came from Stokes County, near Danbury, in 1897 or thereabout. These are the last known specimens of the native beaver to be taken in North Carolina. In 1903, beaver were reported still to occur in Bertie, Buncombe, Forsyth, and Guilford Counties. A planting of beaver from Pennsylvania was made in Richmond County in 1939. Three or more colonies are known to be present from that stocking. Beavers have become established in Yancey and Mitchell Counties, although their source is unknown. A former colony on Bent Creek in Buncombe County has disappeared.

*Notes on the Eighth North American Wildlife Conference.* WILLIS KING.

The Eighth North American Wildlife Conference was held in Denver, Colorado, February 15, 16, 17, 1943. Two principal themes dominated the discussions: the first was the development of plans for seeking release of ammunition for the 1943 hunting season; the second subject dealt with the utilization of coarse or rough fish as food, and sought means of obtaining and marketing species which in the past have been overlooked. A committee was appointed, representing the several states, to cooperate with the Fish and Wildlife Service in an effort to obtain the release of ammunition for hunting purposes. A representative of the War Production Board was present, and assurance was given that that Board was willing to listen to the desires of the State and Federal fish and game authorities in this matter.

It was proposed that if ammunition is released, it will be available to sportsmen through the regular channels of trade. The conference opposed any plan whereby game would be harvested by paid hunters, since past records show that this is both costly and wasteful of the natural resources. Statistics were presented showing that at least 253 million pounds of game were harvested in 1942. Commercial and other marketable fishes were reported to be the third largest source of protein foods, second only to pork and beef.

Throughout the conference the opinion was expressed that the greatest single



contribution which state game and fish departments could make to the war effort would be through a utilization of fishes now usually classed as coarse, rough, or trash varieties. Each state was urged to see if some plan could not be put in early operation whereby these species might be taken in sufficient quantity to aid in the food problem.

The Fish and Wildlife Service is inaugurating a plan whereby cooperation will be given commercial fishermen in obtaining necessary nets, boats, and fishing gear. An additional program is also needed in many localities to stimulate an interest in varieties of fishes which are edible and nutritious, but which have not been popular in local markets. It is thought that the taking of coarse fish can best be carried on by encouraging small operators. Several states now have paid crews engaged in this work.

Several recent developments in fish and pond management were brought out in the technical sessions. One investigator reported that the average annual production on a pond which had been under observation for twelve years was increased from 34 pounds per acre to 274 pounds per acre per year, following the application of fertilizers according to the plan recommended by Swingle and Smith of the Alabama Agricultural Experiment Station. Another report indicated the need to control coarse or rough fish in order to have good fishing for game species. Evidence was presented indicating that if coarse fish dominated the pond or stream, game fish did not thrive.

The general sentiment of the conference was that fish and game have a very important place to fill, in supplying both food and recreation. The states were urged to maintain a balanced program, and to keep before them the more fundamental values in conservation work, in spite of pressure groups which would attempt to make inroads on the fish and game resources.

*The Status of the Modern Amphibia among the Tetrapoda.* F. GAYNOR EVANS.

Comparative osteological studies of representative modern Amphibia (Ichthyophis, Cryptobranchus, Necturus, Rana), a lizard (Iguana), and the rhabdodont labyrinthodont Eryops, a really primitive tetrapod, clearly shows the secondary specialized nature of the living Amphibia. Of 40 different skull elements, excluding the hyobranchial apparatus, present in Eryops 31 are retained by Iguana while in the recent Amphibia the number varies from 20 (Ichthyophis) to 15 (Necturus). The bicondylic condition of modern Amphibia is also a specialization away from the single tripartite condyle of primitive tetrapods. Other skull specializations in living Amphibia are loss of the pineal foramen and of XI and XII cranial nerves; and reduction in the amount of ossification and the number of elements in the hyobranchial apparatus.

Specializations in the postcranial skeleton include the loss of an atlas-axis complex and reduction in the number of elements and the extent of ossification in the girdles (especially the pectoral) and appendages (particularly the carpus and tarsus). The almost complete absence of an exoskeleton and the extreme shortness of the salientian vertebral column are also secondary specializations.

Iguana retains fully developed nearly all the above structures, lost or reduced in living amphibians, and thus is less specialized and resembles more closely the primitive tetrapod condition as represented by the labyrinthodont *Eryops*.

*The Cestodes of North Carolina Poultry with Remarks on the Life History of Raillietina tetragona.* REINARD HARKEMA.

Five hundred chickens from various parts of North Carolina have been examined for tapeworms. Of these 254 or 50.8% were found to be infected with one or more species of cestode. The species found are: *Raillietina tetragona*, *Hymenolepis carioca*, *R. cesticillus*, *R. echinobothrida*, and *Choanotaenia infundibulum*. Numerous cases of mixed infections were found. In the majority of such cases two species were present but occasionally three species were found.

*Raillietina tetragona* is the most prevalent species, being present in 69.98% of the infected birds. It has been known for some time that ants serve as the intermediate host of this species. However, the mode of infection of the ants has not been accurately determined. All attempts to infect worker ants with *Raillietina tetragona* proved unsuccessful. Epidemiological studies to determine more accurately the life history were carried on. Three species of ant of the genus *Pheidole* namely, *P. vinelandica*, *P. dentata*, and *P. sp.* (*fallax* Mayr group), were found to harbor the cysticercoids. Comparatively few specimens of the last two species were examined but both workers and soldiers were found to be infected. Workers, soldiers, pupae, and one larva of *P. vinelandica* were found to be infected. These results indicate that the ants may become infected during the larval stage by being fed the cestode eggs by the workers. Margery W. Horsfall (J. Parasitol. 24 (5): 409-421, 1938) made extensive collections of ants and was unsuccessful in obtaining infected worker ants before June of any one year. She maintained that the infected workers found after June became infected during their larval stage since they probably represented the larvae of spring. The results reported here agree with her conclusions and substantiate them to a certain extent.

*The Lymph System as Main Factor in Regeneration of Oligochaetes.* EMIL LIEBMANN.

The lymph of several oligochaetes investigated carries two types of cells: (a) leucocytes, predominantly of a phagocytic nature, and (b) eleocytes. The latter are liberated chloragogue cells carrying nutritive and activating substances derived from the digestive system into all the organs. They represent genuine trephocytes.

In regeneration the eleocytes act as organized bodies or organs which are formed by accretion of these cells and a small fraction of phagocytes. They exhibit a well outlined function: that of bringing about regeneration.

In the Brandling there are two kinds of these organs: one, permanent, is instrumental in head regeneration; the other is formed during, and active in, tail restitution. The two kinds show specific characteristics in structure, func-

tion, and cell discharges. They each seem to have a specific morphogenetic function. Both these organs exhibit a functional polarity which seems to determine the polarity of the regenerate.

The gradient and limits of head regeneration appear to be determined by the distribution and way of functioning of the eleocytic head organ; those of the tail by the quantitative differential and extent of the chloragogue tissue, which supplies the eleocytes for the tail organ. Size of the regenerant and body region have no direct bearing on regeneration potency.

Regeneration and its various aspects thus appear to be determined by a single, though complex factor: the lympho-trophic or chloragogue system.

*Effects of Burning-over and Raking-off Litter on Certain Soil Animals in the Duke Forest.* A. S. PEARSE.

For five years macroscopic litter and soil animals were collected every three months from three plots in a pine stand in the Duke Forest. Each collection covered an area of 36 sq. ft. of litter and in soil to a depth of 3 in. From the three plots the following numbers of animals were collected:

Intact —litter: 1675; soil: 603;  
total: 2278; 59%

Burned—litter: 659; soil: 208;  
total: 867; 22.5%

Raked —litter: 149; soil: 569;  
total: 718; 18.5%

Removal of litter changes soil as a habitat for animals and many of them die or decrease in numbers. Burning-over apparently is not as detrimental as complete removal of forest litter by raking.

# PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY

OCTOBER 13, 1942, TO MAY 11, 1943

418TH MEETING, OCTOBER 13, 1942

WILLIAM J. BOWEN: *Some Factors Involved in the Formation of Food Vacuoles in the Ciliate Vorticella.*

FRANK N. LOW: *The Measurement of Peripheral Vision.*

At this meeting E. C. Pliske was elected secretary-treasury for the current academic year, in the absence of R. J. Wherry who had previously been elected to this office.

419TH MEETING, NOVEMBER 10, 1943

JAMES C. ANDREWS: *The Metabolism of Quinine.*

H. W. BROWN AND E. WALTZKY: *Studies on the Mode of Action of Quinine on the Malaria Parasite.*

420TH MEETING, DECEMBER 8, 1942

E. BRECHT: *Quinine Substitutes in the Treatment of Malaria.*

M. WHITTINGHILL: *Sex Difference in Amount of Gene Linkage in Drosophila melanogaster.*

421ST MEETING, JANUARY 12, 1943

WILLIAM DANIEL: *Higher Order Cooperation in Rats.*

Due to the illness of S. B. Knight, a paper which was to be given by him at this meeting was postponed.

422ND MEETING, FEBRUARY 9, 1943

ARTHUR ROE: *Some Chemical Components of the Tubercle Bacillus.*

D. P. COSTELLO: *The Beadle-Ephrussi Method for the Transplantation of Eyes of Insects.*

423RD MEETING, MARCH 9, 1943

CLAUDE VILLEE: *Homoeosis.*

S. B. KNIGHT: *Photometric Instruments of Chemical Analysis.*

424TH MEETING, APRIL 13, 1943

W. F. PROUTY: *The Strategic Mineral Situation in the Southeastern United States.*

W. L. FLEMING: *Immunity in Syphilis.*

425TH MEETING, MAY 11, 1943

S. H. HOPPER: *Some Chemical Aspects of the Cancer Problem.*

W. C. COKER: *Interesting Features in the Genus Smilax.*

President Rosenau announced the honor which has been bestowed upon Dr. John N. Couch in his recent election to the National Academy of Science.

Dr. W. C. Coker announced that the various publications of the University plan to issue special numbers for the Sesquicentennial Celebration, and suggested that the Elisha Mitchell Society cooperate in the preparation of an enlarged volume of this Journal. After some discussion it was decided that the present editorial board, with two additional members, should constitute a special committee with full power and responsibility for the preparation and publication of the special Sesquicentennial volume of the Journal. (President Rosenau later appointed Dr. R. W. Bost and Dr. Otto Stuhlman as the additional members and Dr. W. F. Prouty to serve in place of Dr. Gerald MacCarthy who is on leave.)

It was moved and passed that \$75.00 of the Society's savings account should be invested in Series E. Government Bonds.

The following officers were elected for the year 1943-44:

*President*—H. M. Burlage.

*Vice-President*—J. B. Bullitt.

*Secretary-Treasurer*—E. A. Brecht.

The present editorial board and the permanent secretary continue.

# THE FRESH-WATER ALGAE OF NORTH CAROLINA<sup>1</sup>

BY L. A. WHITFORD

## PLATE 21

This paper presents an annotated list of all published records of fresh-water algae collected in North Carolina, together with the records of a state-wide survey made by the writer during the past ten years and a survey of the blue-green algae by Leatherwood (1942). Over 1400 collections, made at all seasons, and from all sections of the state, have been examined by the writer.

More than three quarters of a century ago Curtis (1867) published a catalogue of the plants of North Carolina, including a few species of fresh-water algae. During the succeeding 63 years there was only one paper on the fresh-water algae of the state. This was a list of 81 desmids from Wake County published by Poteat (1888). There were, however, published records of eight other species (Wood, 1872; Atkinson, 1890, 1908; Transeau, 1926). Since 1930 records have been more frequent but the total is still well below 200 species. The following investigators, in addition to those mentioned above, have published records of species collected in North Carolina: Couch, 1932; Whitford, 1936, 1938; Stewart, 1937; Drouet, 1938, 1939A; Coker and Shanor, 1939; Philson, 1939.

The acid waters of the coastal plain region, which comprises about one-half the area of the state, support a much richer and more varied algal flora than do those of the other two geologic regions. The floras of the mountain and piedmont regions, on the other hand, are so similar it is hardly worth while to consider them separately except for seasonal relations.

In the annotated list below there are occasional notes on the taxonomy, morphology, or reproduction of species and varieties as well as the usual distribution and seasonal notes. The following new forms are described: *Tomaculum catenatum* gen. & sp. nov. (Scenedesmaceae), *Chlamydomonas fenestrata*, *C. patellaria*, *Trachelomonas armata* var. *spinosa*, *Synura caroliniana*, *Phaeosphaera perforata*. The list comprises 199 genera, 599 named species, 57 additional varieties, and 6 forms. The systematic arrangement used, while not necessarily the best, is that of Smith (1938). ✽

## CHLOROPHYTA

### CLASS CHLOROPHYCEAE

#### Order Volvocales

#### Family Polyblepharidaceae

#### *Polyblepharides singularis* Dangeard<sup>2</sup>

Cells naked, ovoid,  $7.5-9 \times 12-15 \mu$ , flagella nearly as long as the cell, with 2-4 contractile

<sup>1</sup> This paper is part of a dissertation presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School of The Ohio State University. Papers from the Department of Botany, The Ohio State University, No. 445.

Most of the collections examined by the writer were made with the aid of the North Carolina State College research fund.

<sup>2</sup> The arrangement of genera is that used by Smith in Fresh-water Algae of the United States. The species are arranged alphabetically under the genus.

vacuoles at the base of the flagella, a conspicuous pyrenoid in the posterior third of the cell, and a brown eyespot at the same level.

Although it was collected in a habitat similar to that where *P. fragariiformis* Hasen was found, the species is undoubtedly the one given above. The cells average smaller than in Hasen's species, the flagella are longer, and the position of the eyespot is definitely posterior. The number of contractile vacuoles, however, may be that recorded for either species—2 or 4.

This seems to be the second record for this species and the first for North America.

Forming a green scum on a temporary pool in a field with peat soil just west of Bayboro, Pamlico Co. (c), July, 1937.<sup>3</sup>

#### Family Chlamydomonadaceae

##### *Chlamydomonas fenestrata* sp. nov.

Cells broadly ovoid, 15-18 × 16-19 μ, papillate. Chloroplast a thick massive cup occupying most of the protoplast. It is pierced by irregularly shaped alits over its entire surface. The posterior region is occupied by a large ovoid pyrenoid. The eyespot is brown and in the anterior third of the cell. Flagella as long as the cell.

The species resembles *C. reticulata* except that the chloroplast is more massive and contains a pyrenoid. Fig. 1.

The species was abundant during the entire winter of 1940-41 in a rain-pool near Rocky Branch south of the State College Campus, Wake Co. (p).

##### *Chlamydomonas patellaria* sp. nov.

Cells nearly spherical, 14-15 × 17-18 μ. Cell wall very thin. Chloroplast thin, in the form of a shallow bowl with a discoid pyrenoid near its bottom. The brown eyespot is median or posterior. Flagella about as long as the cell. Fig. 2.

In shape of cell and thickness of wall the species resembles *C. ametastatos* Moewus but differs in size, shape of chloroplast and pyrenoid, and the presence of an eyespot.

The species has been collected once only. It was abundant in a small deep pot-hole in granite rock along the creek just above Mitchell's Mill Pond in northeastern Wake Co. (p), February, 1941.

##### *Chlamydomonas pertyi* Goroshankin

Apparently our most common species. It, along with euglenoids, frequently produces bloom on small pools, especially in barnyards, in early spring. Conjugation of elongate-ovoid isogametes of this species has been observed.

Widespread in small piedmont pools, winter and spring.

##### *Chlamydomonas platystigma* Pascher.

In one small sewage-contaminated pool, Wake Co. (p), May.

##### *Lobomonas rostrata* Hazen

From an aquarium, Wake Co. (p), March.

##### *Furcilia lobosa* Stokes

From a new concrete swimming pool, Wake Co. (p), May.

##### *Carteria globulosa* Korshikoff

From a gold fish pool, Wake Co. (p), April.

#### Family Phacotaceae

##### *Pteromonas angulosa* Lemmermann

Cells 9-10 × 12-14 μ.

Seepage pool in a pasture, Wake Co., March.

##### *Pteromonas* sp.

Present in the plankton of a Wake Co. (p) pond, May.

<sup>3</sup> Where no collector is mentioned the form is from the herbarium of the writer. Distribution is given by region and season if data are sufficient, otherwise by county and month. The abbreviations for the regions are: (m) mountain, (p) piedmont, (c) coastal plain.

## Family Volvocaceae

*Gonium pectorale* O. F. Müller

Widely distributed in the plankton of piedmont and coastal plain ponds in spring and autumn.

*Gonium sociale* (Duj.) Warming

Goldfish pools, Wake and Durham Cos. (p), April.

*Pandorina charkowiensis* Korshikoff

Fusion of the gametes of this species has been observed. The gametes are unlike in size but both swim, proving that the species belongs to the genus *Pandorina*. Apparently it is widespread in the plankton of the lower piedmont and coastal plain. Found abundant once in a goldfish pool in Wake Co. (p) in winter; in a slow stream and a pond in Craven Co.; and in a ditch in Washington Co. (c), September to June.

*Pandorina morum* Bory

Widespread and locally abundant throughout the state, especially in small pools, autumn, winter, and spring. (Roller, Whitford).

*Eudorina elegans* Ehrenberg

Generally distributed in the plankton. More abundant in the cooler months and in small pools.

*Eudorina unicocca* G. M. Smith

Rare in the plankton of three ponds, Camden, Moore (c), and Wake (p) Cos., spring and autumn.

*Volvox aureus* Ehrenberg

Rare in several Wake Co. (p) ponds, spring.

*Volvox mononae* G. M. Smith

Rare in the plankton of an eastern Wake Co. (c) pond, June.

*Volvox perglobator* Powers

Reported by Roller from one Wake Co. (c) pond.

## Family Sphaerellaceae

*Sphaerella lacustris* (Girod.) Wittrock

Generally distributed throughout the state in pools or small ponds where lime is available.

In marble and concrete basins and pools in the east and depressions in rocks in the west. At times so abundant as to give the water a deep brick-red color. Present all year but most abundant during the cooler months.

Since it has been found in the mountains of Virginia there is no reason to believe that *Stephanosphaera pluvialis* Cohn does not occur also in the North Carolina mountains.

It has been collected in pools in rock ledges near Marion, Virginia, but not in this state.

## Order Tetrasporales

## Family Palmellaceae

*Palmella mucosa* Kuetzing

From the border of one coastal plain pond, Washington Co., April.

*Sphaerocystis schroeteri* Chodat

In the plankton of a Wake Co. (p) pond, April.

*Gleocystis gigas* Kuetzing

Occasional colonies are encountered among vegetation at the edge of ponds, Buncombe, Cherokee (m), Wake (p), and Craven and Moore Cos. (c), January to June.

*Gleocystis vesiculosa* Naegeli

Collected with plankton algae in two coastal plain ponds, Cumberland and Wayne Cos. (c), spring.

*Palmodictyon varium* (Naeg.) Lemmermann

Several small elongate colonies have been collected in two Wake Co. (p) ponds, February.

*Asterococcus limneticus* G. M. Smith

In the plankton of a Cumberland Co. (c) pond, May.



## Family Tetrasporaceae

*Tetraspora cylindrica* (Wahlb.) Agardh

Occasionally seen in Wake Co. (c, p) ponds in early spring.

*Tetraspora lubrica* (Roth.) Agardh

Generally distributed and locally abundant in ponds and brooks in winter and early spring. Reported at Salem, Forsyth Co. (p) by Wood (1872).

## Family Coccomyxaceae

*Elakatothrix gelatinosa* Wille

Widespread but never abundant in the plankton of the coastal plain.

*Chlorosarcina consociata* (Klebs) G. M. Smith

From the leaves of *Lemma minor* in a Dare Co. (c) pond, May.

## Order Ulotrichales

## Family Ulotrichaceae

*Ulothrix tenerrima* Kuetzing

Several small species of *Ulothrix* are found among other filamentous algae in early spring.

The above species is present as late as April in Wake Co. (p) ponds.

*Stichococcus bacillaris* Naegeli

Common on moist rotting wood and leather in Wake Co. (p), winter and spring.

*Binuclearia tatrana* Wittrock

Rare among vegetation in two coastal plain ponds, Bladen Co. (c), March, Carteret Co. (c), January.

## Family Microsporaceae

*Microspora quadrata* Hazen

Several species of *Microspora* are common among other filamentous algae in early spring and may persist in cold waters until May. The above species is from a shady pool in Wake Co. (p), April.

*Microspora tumidula* Hazen

This species has been found in autumn as well as in spring in clear cool pools, Craven Co. (c), Wake Co. (p), October and May.

*Microspora willeana* Lagerheim

From one coastal plain pond, Wayne Co. (c), April.

*Microspora wittrockii* Lagerheim

From an eastern swamp, Perquimans Co. (c), April.

*Cylindrocapsa geminella* Wolle

From cool marshy brooks, Wake Co. (p), April.

## Family Chaetophoraceae

*Stigeoclonium stagnatile* (Hazen) Collins

In a shady spring, Wake Co. (p), April.

*Stigeoclonium* is a winter and early spring form in North Carolina and disappears, except in shady springs, after May first.

*Stigeoclonium tenue* (Sammelart) Kuetzing

From the shallows of a Wake Co. (p) pond, March.

*Chaetophora attenuata* Hazen

Collected for several years in a cool shady woodland pool in Wake Co. (p), April.

*Chaetophora pisiformis* Agardh

Generally distributed, on sticks and leaves, in shallow water, throughout the winter and early spring.

*Draparnaldia acuta* Kuetzing

In running water in early spring, Wake Co. (c).

*Draparnaldia glomerata* Agardh

The common piedmont species. In brooks, early spring.

*Draparnaldia platyzonata* Hazen

Frequent in Wake Co. (p) brooks, February to April.

*Draparnaldia plumosa* Agardh

In springs and shady pools, Wake Co. (p), February and March.

*Aphanochaete repens* A. Braun

On filamentous green algae, lower piedmont and coastal plain, spring and early summer.

*Aphanochaete vermiculoides* Wolle

Collected in the sheath of *Hyalotheca mucosa* in two Wake Co. (p) ponds, February and September.

*Aphanochaete* sp.

A species, apparently neither of the preceding, is epiphytic on juvenile plants of a species of *Batrachospermum* in White Lake, Bladen Co. (c), April.

#### Family Saprochaetaceae

*Saprochaete saccharophila* Coker & Shanor

This colorless saprophytic species has been placed in a separate family by its authors.

It has been collected by Coker and Shanor in streams in Chatham and Orange Cos. (p), spring.

#### Family Protococcaceae

*Protococcus viridis* (Ag.) Wille

Common on tree trunks, stonework, and rotting wood, especially near barns. First reported by Curtis (1867).

At least one or two other species are present in our flora.

#### Family Coleochaetaceae

*Coleochaeta scutata* Brébisson

Widespread on the sheaths of *Typha* leaves and on aquarium walls in spring. Also collected by Blomquist in Durham Co. (p).

*Coleochaete soluta* (Bréb.) Pringsheim

General in the same habitat but not so common as *C. scutata*.

#### Family Cladophoraceae

*Cladophora crystallina* (Roth.) Kuetzing

The low calcium content of our waters probably explains the rare occurrence of this genus so common in many regions. Collected twice in slightly brackish pools near the ocean, Carteret Co. (c), December and January.

*Rhizoclonium hieroglyphicum* Kuetzing

This alga has been found only in aquaria where it had undoubtedly been introduced on aquatics or fish.

*Basycladia chelonum* (Collins) Hoffman and Tilden

The average size and the structure of my material agrees with the description of the above species, but the upper cells in a few filaments may exceed 50  $\mu$  in diameter. The occasional upper branches diverge at nearly right angles from the main filament.

In May, 1940, the liberation of zoospores was observed in material collected in Wake County (p). A papilla appeared on swollen upper cells which opened suddenly into a pore from which small biflagellate zoospores emerged at the rate of about four a second until more than 100 had been liberated. The motile bodies (which are ovoid and about 5  $\mu$  in diameter) from different cells swam about together for several hours without any signs of conjugation, indicating that they were zoospores.

The species is almost invariably present on several species of turtles, especially the common mud turtle. Several collections in Wake (p), Nash, Bladen, and Craven (c) Cos., May, June, July.

*Pithophora kewensis* Wittrock

From several aquaria, Wake Co. A species, probably the above, is reported from several outdoor ponds in Durham Co. (p) by Blomquist. Spring and summer.

## Order Oedogoniales

## Family Oedogoniaceae

*Oedogonium ahlstrandii* Wittrock

From a swamp in New Hanover Co. (c), March.

*Oedogonium borisianum* Wittrock

In and near Mattamuskeet, Hyde Co. (c), May.

*Oedogonium boscii* var. *occidentale* Wittrock

From two Wake Co. (p) ponds, April and May.

*Oedogonium braunii* Kuetzing

Attached to stems of aquatic plants in Yates pond, Wake Co. (c), May.

*Oedogonium braunii* var. *zehnerii* Kuetzing

From a ditch in Wake Co. (p), April.

*Oedogonium crassiusculum* var. *idioandrosporum* Nordstedt and Wittrock

Among other filamentous algae in a Wake Co. (c) pond, June.

*Oedogonium crispum* Wittrock

Fruiting in Wake Co. (p), April.

*Oedogonium crenulatoconiatum* Wittrock

From two pools in Wake Co. (p), July and August.

*Oedogonium decipiens* Wittrock

From a small pool in Hyde Co. (c), May.

*Oedogonium fragile* Wittrock

From a small pool, Wake Co. (p), July.

*Oedogonium inerme* Hirn

It is not certain male plants of this species have been seen; other details check perfectly, however. Wake Co. (c), March.

*Oedogonium kurzii* Zeller

This species has been found in fruit only in quiet pools below rapids. In these rapids a species grows perennially which is vegetatively identical with it. I believe that this species is *Oe. kurzii*. It has been collected dozens of times throughout the state, always on rocks in rapids, and is present in the piedmont throughout the year. Fruiting in Wake Co. in June.

*Oedogonium longicollae* var. *senegalense* Nordstedt

In a swampy pond, Wake Co. (p), April.

*Oedogonium macrandrium* var. *hohenackerii* (Witt.) Tiffany

On the shady side of a Wake Co. (p) pond, April.

*Oedogonium macrandrium* var. *propinquum* (Witt.) Hirn

Wake Co. (p), April.

*Oedogonium mammiferum* Wittrock

From one eastern bog lake, Bladen Co. (c), May.

*Oedogonium nitratum* Hirn

From a shady pool, Wake Co. (p), April.

*Oedogonium nebraskense* Ohashi

From the Raleigh City Reservoir, Wake Co. (p), April.

*Oedogonium nodulosum* Wittrock

In a New Hanover Co. (c) swamp, March.

*Oedogonium oedlandicum* Wittrock

From a cypress pond, Craven Co. (c), May.

*Oedogonium oryzae* Wittrock

From a goldfish pool, Wake Co. (p). Very abundant and fruiting in May.

*Oedogonium pringsheimii* var. *nordstedtii* Wittrock

From a temporary pool, Hyde Co. (c), May.

*Oedogonium pungens* Hirn

Fruiting in Wake Co. (p) in late April and in Bladen and Harnett Cos. (c) in early May.

*Oedogonium reinschii* Roy

In a cypress pond, Onalow Co. (c), December.

*Oedogonium sexangulare* Cleve

From one Wake Co. (c) pond, May.

*Oedogonium suberectum* Hirn

Wake Co. (p), spring.

*Oedogonium suecicum* var. *australe* G. S. West

From two ponds in Wake Co., April and May.

*Oedogonium undulatum* (Bréb.) A. Braun; Wittrock

In Lake Mattamuskeet, Hyde Co. (c), May.

*Bulbochaete crassiuscula* Nordstedt

From a sandhill pond, Moore Co. (c), June.

*Bulbochaete elatior* Pringsheim

This species from an old collection near Raleigh in 1928 is doubtfully reported, Wake Co., spring.

*Bulbochaete furberae* Collins

From one Wake Co. (p) pond, April.

*Bulbochaete insignis* Pringsheim

Epiphytic on stems or other algae in piedmont ponds, spring.

*Bulbochaete nordstedtii* Wittrock

On vegetation in a ditch near New Holland, Hyde Co. (c), May.

*Bulbochaete pygmaea* Pringsheim

Cells  $11.7-13.5 \times 11.7-13 \mu$ . A few curved filaments of a tiny epiphytic species is doubtfully referred to the above species. Harnett Co. (c).

*Bulbochaete spinosa* Wailes

A plant which is almost certainly the above species has been very abundant for several years, from March until mid-summer, in a pond at Rocky Mount, Nash Co. It has never been collected in fruit. Cells  $24-27 \times 60-76 \mu$ . All ordinary cells except the hold-fast cell uniformly covered with spines  $2 \mu$  in length.

Nash and Wake Cos. (c), first collected, April, 1941.

*Bulbochaete varians* Wittrock

From several Wake Co. (c) ponds, March and April.

*Oedocladium lewisii* L. Whitford

Since this species was first collected near Raleigh, N. C., October, 1938, it has been found at twenty-two widely separated stations in nine counties of the state. It is always found, along with moss protonema and thalloid liverworts, on recently disturbed sandy or loam soil, usually in bottom-land fields. Cool rainy weather for two weeks or more is probably necessary for it to become abundant enough to be readily collected. It grows in scattered tufts that, to the naked eye, closely resemble moss protonema, under weeds and grass on soil almost wet enough to be muddy. It is most frequent in autumn but has been collected every month of the year except February.

In the mountains it has been collected in Ashe Co., August; in the piedmont in Durham, Orange, and Wake Cos., October to November and May; and in the coastal plain in Beaufort, Craven, Harnett, Lenoir, and Pamlico Cos., June to January.

The species is known only from North Carolina.

Order Ulvales

Family Schizomeridaceae

*Schizomeris liebleinii* Kuetzing

Widespread but never abundant in slow streams in piedmont and coastal plain, spring and summer.

Order Schizogoniales  
Family Schizogoniaceae

*Schizogonium orenulatum* Kuetzing

On stiff wet clay soil in shady situations, Wake Co., February.

*Schizogonium murale* Kuetzing

On wet soil on shady banks and in paths, in autumn, winter, and spring.

Order Chlorococcales  
Family Chlorococcaceae

*Chlorococcum humicola* (Naeg.) Rabenhorst

In wet soils throughout the state. Always present in Raleigh tap water.

*Trebouxia cladonia* (Chod.) G. M. Smith

The algal component in at least several species of foliose and fruticose lichens throughout the state.

*Golenkinia radiata* var. *brevispina* (Chod.) Tiffany and Ahlstrom

In the plankton. Most abundant in goldfish pools. Spring and summer.

Family Endosphaeraceae

*Chlorochytrium lemnae* Cohn

From the leaves of *Lemna minor* collected at Nag's Head, Dare Co., May.

*Rhodochytrium spilanthis* Lagerheim

Parasitic in the leaves of flowering plants. Reported from *Ambrosia artemisiifolia* by Atkinson, Wake Co., summer.

Family Characiaceae

*Characium ensiforme* Hermann

Epiphytic on *Pithophora* and on the walls of aquaria, winter.

*Characium pringsheimii* A. Braun

Epiphytic on filamentous algae in aquaria at Raleigh, Wake Co. (p), winter.

Family Protosiphonaceae

*Protosiphon botryoides* (Kuetz.) Klebs

On damp soil in cultivated fields. I believe this species is fairly common but positively identified only from Craven Co. (c), summer.

Family Hydrodictyaceae

*Pediastrum araneosum* Raciborski

Among filamentous algae in small pool in southern Sampson Co. (c), February.

Also collected in Durham Co. (p) by Blomquist.

*Pediastrum biradiatum* Meyen

From the plankton of a pond in southern Wake Co. (c), November.

*Pediastrum boryanum* (Turp.) Meneghini

Among filamentous algae in Carteret Co. (c) ponds, December.

*Pediastrum boryanum* var. *longicorne* Raciborski

From the plankton of a goldfish pool, Wake Co. (p), April.

*Pediastrum duplex* Meyen

Widespread in the plankton of piedmont and coastal plain, spring.

*Pediastrum duplex* var. *clathratum* (A. Br.) Lagerheim

In the plankton of a coastal plain pond, Wake Co., May.

*Pediastrum duplex* var. *gracillimum* W. & G. S. West

From the plankton, Watauga Co. (m), August, and Wayne Co. (c), June.

*Pediastrum duplex* var. *reticulatum* Lagerheim

Apparently widespread in the plankton. Avery and Watauga Cos. (m), summer, and spring in the piedmont and coastal plain counties.

*Pediastrum duplex* var. *rotundatum* Luicks

Seen in a single collection from Wake Co. (p), October.

*Pediastrum tetras* (Ehr.) Ralfs

Rare but widespread in the plankton in spring.

*Pediastrum tetras* var. *tetraodon* (Corda) Rabenhorst

Collected several times in the piedmont and coastal plain, spring and summer.

*Sorastrum americanum* (Bohlin) Schmidle

From one Craven Co. (c) pond, June and August.

A common species of the middle west, *Hydrodictyon reticulatum* (L) Lagerh., has not been collected in North Carolina. Possibly the low calcium content of our waters makes it very rare or non-existent in this region.

## Family Coelastraceae

*Coelastrum augustae* var. *armatum* Skuja

In the plankton of coastal plain ponds.

*Coelastrum cambricum* Archer

Widely distributed in the plankton of ponds throughout the state. Frequently abundant in goldfish pools in spring.

*Coelastrum cambricum* var. *intermedium* (Bohl.) G. S. West

Among filamentous algae in a Pamlico Co. (c) canal, July.

*Coelastrum chodatii* Ducecllier

Rare in the plankton of one coastal plain pond.

*Coelastrum morus* W. & G. S. West

In aquaria at Raleigh, Wake Co., winter.

*Coelastrum sphaericum* Naegeli

Rare among filamentous algae in several piedmont and coastal plain ponds, spring.

## Family Oocystaceae

*Chlorella conductrix* Brandt

Symbiotic with *Hydra viridis*, and species of *Paramoecium* and *Stentor* throughout the state.

*Chlorella ellipsoidea* Gerneck

Abundant in goldfish pools at Raleigh, Wake Co. (p) in spring.

*Chlorella parasitica* Brandt

Symbiotic with the sponge so common in the brown waters of the southeast and in the cells of the common colonial ciliate *Ophryodinium*, which forms gelatinous colonies up to one decimeter in diameter in the shallows of coastal plain ponds.

*Chlorella vulgaris* Byerinck

The most common species of *Chlorella* in the state. Abundant in aquaria and goldfish pools in winter and spring.

*Westella botryoides* DeWildemann

From the plankton of several piedmont and coastal plain ponds. Not common. Autumn and spring.

*Dictyosphaerium planctonicum* Tiffany and Ahlstrom

Rare in the plankton of one Cumberland Co. (c), pond, May.

*Dictyosphaerium pulchellum* Wood

Common in the plankton in spring, summer, and autumn.

*Eremosphaera viridis* DeBary

Occasional cells are encountered in collections with desmids, spring, and summer.

*Excentrosphaera viridis* G. T. Moore

On moist sandy soil in Carteret Co. (c). October.

*Treubaria crassispina* G. M. Smith

A few cells were seen in the plankton of one Wake Co. (p) pond, October.

*Pachycladon umbrinus* G. M. Smith

Occasional cells are seen in plankton collections from piedmont and coastal plain, spring and summer.

*Oocystis borgei* Snow

Collected a few times in Wake Co. ponds both in the piedmont and coastal plain, May.

*Nephrocystium agardhianum* Naegeli

Apparently rare but occasionally found in plankton collections, February to July.

*Lagerheimia longiseta* Lemmermann

From one goldfish pool at Raleigh, Wake Co. (p), April.

*Lagerheimia subsalsa* Lemmermann

Common in goldfish pools in the piedmont, spring and autumn.

*Franceia tuberculata* G. M. Smith

From a new concrete swimming pool, Wake Co. (p), May.

*Dimorphococcus lunatus* A. Braun

From the plankton of numerous coastal plain ponds, spring and summer.

*Ankistrodesmus falcatus* (Corda) Ralfs

Widespread in the plankton. Abundant in aquaria and goldfish pools.

*Ankistrodesmus falcatus* var. *mirabilis* W. & G. S. West

From the plankton of one eastern bog lake, Bladen Co. (c), May.

*Schroederia setigera* Lemmermann

This species was observed to produce biflagellate, fusiform zoospores  $3-6 \times 7-9 \mu$  in size.

From a rain-pool in a road in a field, Pamlico Co. (c), July.

*Selenastrum bibraianum* Reinsch

From the plankton of several piedmont and coastal plain ponds.

*Selenastrum bibraianum* var. *gracile* Tiffany and Ahlstrom

Rare in the plankton of the coastal plain, spring.

*Selenastrum westii* G. M. Smith

Widespread but never abundant in the plankton, spring.

*Kirchneriella lunaris* (Kirchn.) Moewus

Hyde (c) and Wake (p) Cos., spring.

*Kirchneriella lunaris* var. *dianae* Bohlin

Plankton; Bladen, Wayne (c) and Wake (p) Cos., June.

*Kirchneriella obesa* (W. West) Schmidle

Plankton; Wake Co. (p), May.

*Kirchneriella obesa* var. *aperta* (Teil.) Brunnthaler

Plankton; Wake Co. (p), May.

*Kirchneriella obesa* var. *major* (Bernard) G. M. Smith

Plankton; Lenoir (c) and Wake (p) Cos., spring.

*Kirchneriella* is much more widespread than the above records indicate. Other species and varieties are probably present in our flora.

*Quadrigula chodati* G. M. Smith

From the plankton of one Wake Co. (c) pond, May.

*Quadrigula closterioides* (Bohlin) Printz

Probably widespread in the plankton but it has been seen in two mountain collections only. Polk and Jackson Cos., June.

*Tetradron caudatum* (Corda) Hansgirg

From among aquatic plants in Lake Mattamuskeet, Hyde Co. (c), May.

*Tetradron caudatum* var. *longispinum* Lemmermann

From a swamp in Wilson Co. (c), September.

*Tetradron gracile* (Reinsch) Hansgirg

From a number of piedmont and coastal plain collections. Rare in the plankton, spring and summer.

*Tetradron hastatum* var. *palatinum* Lemmermann

Seen in the plankton of a single Wake Co. (c) pond, May.

*Tetradron limneticum* Borge

From the plankton of several Wake Co. (c, p) ponds, spring.

*Tetradron minimum* (A. Br.) Hansgirg

In two coastal plain ponds, Wake and Wilson Cos., spring and autumn.

*Tetradron quadricuspidatum* (Reinsch) Hansgirg

This species apparently unreported in the United States, was seen in two Wake Co. (p) and one Harnett Co. (c) ponds, spring and autumn.

*Tetradron regulare* Kuetzing

Rare in the plankton of a Harnett Co. (c) bog lake, May.

*Tetradron trigonum* (Naeg.) Hansgirg

Among vegetation in a Wilson Co. (c), swamp, September.

*Tetradron trigonum* var. *gracile* Reinsch

From the plankton of several coastal plain ponds, spring.

*Tetradron trigonum* var. *setigerum* (Arch.) Lemmermann

In a Wilson Co. (c) swamp, September.

## Family Scenedesmaceae

*Scenedesmus abundans* (Kirchner) Chodat

In the plankton, generally distributed, summer.

*Scenedesmus acuminatus* (Lagerh.) Chodat

In the plankton of one Wake Co. (c) pond, May.

*Scenedesmus armatus* (Chod.) G. M. Smith

Plankton; Wake Co. (p), May; Wilson Co. (c), September.

*Scenedesmus armatus* var. *bicaudatus* (Guglielmetti) Chodat

Rare in the plankton of one Wake Co. (p) pond, May.

*Scenedesmus bijuga* (Turp.) Kuetzing

Plankton; coastal plain, spring.

*Scenedesmus bijuga* var. *alternans* (Reinsch) Hansgirg

Plankton, Wake Co. (p), May.

*Scenedesmus braziliensis* var. *costodispar* Ahlstrom

From a pot hole in a stream, Wake Co. (c), June.

*Scenedesmus dimorphus* Kuetzing

In the plankton, piedmont and coastal plain.

*Scenedesmus oahuensis* (Lemm.) G. M. Smith

In a Wilson Co. (c) swamp, September.

*Scenedesmus obliquus* (Turp.) Kuetzing

From a ditch in Hyde Co. (c), May.

*Scenedesmus opoliensis* P. Richter

From the plankton of one mountain and one piedmont pond, spring.

*Scenedesmus parisiensis* Chodat

In a Wilson Co. (c) swamp, September.

*Scenedesmus producto-capitatus* Schumla

In a Wilson Co. (c) swamp, September.

*Scenedesmus quadricauda* (Turp.) Brébisson

General and occasionally abundant in the plankton.

*Scenedesmus quadricauda* var. *abundans* Kirchner

This variety has been seen only in a collection from Hyde Co., May.

*Scenedesmus quadricauda* var. *maximus* W. & G. S. West

Common but not so widespread as the species.

*Scenedesmus quadricauda* var. *westii* G. M. Smith

From one goldfish pool in Carteret Co. (c), December.

*Scenedesmus serratus* f. *minor* (Corda) Bohlin

From a Wilson Co. (c) swamp, September.

*Crucigenia apiculata* var. *ericensis* Tiffany and Ahlstrom

Occasional colonies were seen in two coastal plain collections. Craven and Wake Cos. (c), spring.



*Crucigenia fenestrata* Schmidle

Rare in the plankton of a single Wake Co. (c) pond, May.

*Crucigenia tetrapedia* (Kirch.) W. & G. S. West

Apparently widespread, but never common, spring.

*Tomaculum* gen. nov.

Cells sausage-shaped and curved or with a side process producing a 3-lobed cell; the ends of each cell or lobe connected by a strand with the end of another cell, the whole forming an irregular reticulum of about 20 cells. Chloroplasts one or two, parietal, band-like, about half encircling the cell; a pyrenoid in each. Colony surrounded by a wide pectin sheath. Reproduction has not been observed.

The genus may be placed in the Scenedesmaceae near the genus *Tetrallantos*.

*Tomaculum catenatum* sp. nov.

Cells 6-8  $\times$  18-60  $\mu$ ; colony (without sheath) about 30  $\times$  300  $\mu$ . Other characters as described for the genus. Figs. 3-4.

The shape of the unbranched cells is somewhat similar to that of the cells of *Tetrallantos lagerheimii* Teil. but the branched cells and reticulate arrangement of the cells are unique.

The species was collected in water about one foot deep, among masses of filamentous algae and aquatics, in Partin's Pond, an old mill pond in southern Wake Co. (c), in November, 1940.

*Tetrastrum staurogeniaeforme* (Schroed.) Lemmermann

General in piedmont and coastal plain plankton, spring and summer.

*Tetrallantos lagerheimii* Teiling

This rare species was first discovered in the plankton of a Cumberland Co. (c) pond in 1935.

The next year it was frequent in a Wake Co. (c) pond. May and June.

*Actinastrum hantzschii* var. *fluvatile* Lemmermann

Among filamentous algae in a slow creek, Craven Co. (c), June.

*Micratinium pusillum* Fresenius

From several Wake Co. (p) ponds, spring.

## Order Siphonales

## Family Vaucheriaceae

*Vaucheria arrhyncha* Heidinger

*Vaucheriopsis arrhyncha* (Heidinger) Heering

Oogonia (one or sometimes two) borne on lateral branches at right angles to and somewhat smaller than the main filament. The fruiting branch is straight with one or two pedicels curving gracefully downward. Antheridia tubular, hooked, opening by a single terminal pore; on a short stalk which is turned sharply downward from its point of attachment at the base of the pedicel and at right angles to it. Chloroplasts often grouped in center of antheridium. Oogonium spherical, without a beak, opening by a pore or slit. Oospore spherical, with two thin membranes, filling oogonium, and remaining green after maturity. Filaments 75-123  $\mu$  in diameter; oogonia 140-160  $\mu$  in diameter; antheridia 50-53  $\mu$  in diameter.

Heidinger reports this species as differing from all other species of *Vaucheria* in four ways: (1) plant without oil, (2) oospore with a single membrane and remaining green, (3) fertilization not accompanied by expulsion of protoplasm, (4) absence of a beak on the oogonium.

In the American material there is abundant oil in both filaments and spores. Direct observation as well as several oil tests prove this. There is no starch even when the plants are kept for weeks under constant illumination.<sup>4</sup> The oospore has two thin

<sup>4</sup> If IKI alone is used as a test for starch there is a chance of error in regard to the presence of starch. In old filaments dark granules are frequently present which resemble starch grains after the application of an iodine solution. These are not doubly refractive, however, under polarized light.

membranes of equal thickness.<sup>5</sup> Thin spore membranes are also found in *Vaucheria intermedia* and *V. piloboloides*. It is my opinion that the two remaining differences, concerning the oogonium only, are not sufficient to warrant placing the species in a separate genus.<sup>6</sup>

The species has been collected each spring for seven years at several stations in the lower piedmont and coastal plain, always in cool flowing water. Fruiting in late April and May.

Dr. C. E. Taft has recently collected the species on wet soil in Ohio.

Previously known only from Germany.

*Vaucheria aversa* Hassall

From springs in winter and wet soil in spring and autumn, Wake Co. (p). Also reported from Orange Co. by Couch. Fruiting November to March.

*Vaucheria geminata* DeCandolle

In shallow quiet water, Wake Co., February to April.

Also from Orange Co. (Couch).

The *longipes* type is also occasionally collected.

*Vaucheria hamata* (Vauch.) DeCandolle

From wet soil and slow streams, Wake (p), and Pitt and Craven (c) Cos., spring and autumn.

*Vaucheria litorea* Agardh

From slightly brackish water in a ditch near Carolina Beach, New Hanover Co. (c), April.

*Vaucheria ornithocephala* Agardh

Found only in rapids or waterfalls where it fruits abundantly. Wake and Orange Cos. (p), March and April.

*Vaucheria pachyderma* Walz

Reported from Orange Co. (p) by Couch. Fruiting in March.

*Vaucheria repens* Hassall

From wet soil and shallow water Wake (p) and Cherokee (m) Cos., spring.

*Vaucheria sessilis* (Vauch.) DeCandolle

First reported from the state by Wood (1872) from a collection by von Schweinitz. Common in shallow water in the piedmont in winter and spring.

*Vaucheria terrestris* Lyngbye

Common on wet soil everywhere, autumn, winter, spring.

Order Zygnematales

Family Zygnemataceae

*Mougeotia capucina* (Bory) Agardh

From a ditch in Pender Co. (c) (Transeau), March.

*Mougeotia depressa* (Hass.) Wittrock

From the edge of Page's Lake, Bladen Co. (c), May.

*Mougeotia megaspora* Wittrock

In a cypress pond in southern Craven Co. (c), May.

*Mougeotia nummuloides* (Hass.) De Toni

Pender Co. (c), March (Transeau), Wake Co. (p) (Whitford).

*Mougeotia operculata* Transeau

Wake Co. (p), spring.

*Mougeotia ovalis* (Hass.) Nordstedt

From a temporary pool, Pender Co. (c), June.

*Mougeotia parvula* Hassall

Reported from Pender Co. (c) by Transeau, March.

<sup>5</sup> These layers can more easily be seen if slightly swollen with strong sulfuric acid.

<sup>6</sup> In *Vaucheria litorea* and *V. piloboloides* the oogonia are without, or practically without a beak.

*Meugeotia quadrangulata* Hass.

Bladen Co. (c) (Whitford), Pender Co. (c) (Transeau), March.

*Meugeotia sphaerocarpa* Wille

Wake Co. (p), spring.

*Meugeotia tubifera* Tiffany

From a marsh in Brunswick Co. (c), March. Known only from Florida and North Carolina.

*Zygnema carinhiacum* Beck

From the shallows of Lake Raleigh, Wake Co. (p), April.

*Zygnema coeruleum* Czurda

From a shallow pond, Wake Co. (p), February.

*Zygnema luteosporum* Czurda

From the coastal plain section of Wake Co., May.

*Zygnema pectinatum* (Ag.) Czurda

Lake Raleigh, Wake Co. (p), April.

*Zygnema sterile* Transeau

Non-fruiting material of what is apparently the above species is common in the acid waters of eastern ponds in spring. Bladen, Craven, Pender, Onslow Cos.

*Zygnema subcruciatum* Transeau

Wake Co. (p), April.

*Zygogonium ericetorum?* Kuetzing

From wet soil in Wake Co. (not fruiting).

*Spirogyra aphanosculpta* Skuja

In a seepage pool on a hillside, Wake Co. (p), April.

*Spirogyra cleveana* Transeau

This species is reported with certainty from only one locality; pools in Linville River, Pineola, Caldwell Co. (m), June. It is believed, however, that several piedmont collections recorded as *S. protecta* Wood are really this species.

*Spirogyra hatillensis* Transeau

From the edge of Lake Raleigh, Wake Co. (p), May.

*Spirogyra majuscula* Kuetzing

Reported from the state by Transeau.

A species, probably the above, fruits at Raleigh (Wake Co.) in April.

*Spirogyra malmeana* Hirn

Fruiting in an eastern Wake Co. (c) pond, June.

*Spirogyra protecta* Wood

This species is reported from Durham County (p) by Blomquist as quite common. In my early notes the species is listed several times. A careful check of these collections shows the species to be *S. cleveana*. Because *S. protecta* is common and widespread it is listed, although no North Carolina material has been compared with type material.

*Spirogyra reflexa* Transeau

In a marshy pool in Macon Co. (m), June.

*Spirogyra singularis* Nordstedt

A few fruiting filaments of a species probably the above one were seen in the collection with *S. reflexa*. Macon Co. (m), June.

*Spirogyra submarina* (Collins) Transeau

Wake Co. (c), May.

## Family Mesotaeniaceae

*Mesotaenium endlicherianum* Naegeli

Reported from near Wake Forest, Wake Co. (c) by Potest.

*Gonatozygon aculeatum* Hastings

Occasional cells in my collections approach 300  $\mu$  in length but the average falls well within the recorded average.

In the plankton of coastal plain ponds, Bladen and Cumberland Cos., May.

*Gonatozygon monotaenium* De Bary

Rare in eastern Wake Co. (c) ponds.

*Gonatozygon pilosum* Wille

Occasionally abundant in piedmont or coastal plain ponds. Bladen and Wake Cos., spring.

*Gonatozygon* sp.

One unidentified species which forms filaments of indefinite length is common at times in the black waters of coastal plain ponds.

*Netrium digitus* (Ehr.) Itzigsohn and Rothe

Occasional cells are found in desmid collections throughout the state, spring and summer. Also reported by Poteat.

*Netrium interruptum* (Bréb.) Luetkmueller

Not as frequent as the species above but apparently widespread in all parts of the state, spring and summer. Mitchell Co. (m) (Brown), Onslow, Pitt, and Wake (c) Cos. (Whitford), Wake Co. (p) (Poteat).

*Netrium oblongum* (DeBary) Luetkmueller

Reported from Mitchell Co. (m) by Brown.

*Spirotaenia condensata* Brébisson

From several piedmont ponds, spring. Wake Co. (Poteat).

*Spirotaenia obscura* Ralfs

Reported from Mitchell Co. (m) (Brown) and Wake Co. (p) (Poteat).

#### Family Desmidiaceae

*Closterium abruptum* (Lyngb.) Brébisson

In ooze on the bottom of a rain pool, Wake Co. (p), September.

*Closterium acerosum* (Schrank) Ehrenberg

From a small roadside pool in Craven Co. (c), August (Whitford); Wake Co. (p) (Poteat) and Mitchell Co. (m) (Brown).

*Closterium acutum* Brébisson

Reported only by Poteat from Wake Co. (p).

*Closterium angustatum* Kuetzing

From the shallows of one Anson Co. (p) pool, April.

*Closterium archerianum* Cleve

Wake Co. (p), spring.

*Closterium areolatum* Wood

Wake Co. (p) (Poteat).

*Closterium cornu* Ehrenberg

In a small marshy stream, Onslow Co. (c), August.

*Closterium costatum* Corda

Among other algae in a swampy creek, Pamlico Co. (c), August.

*Closterium cynthia* De Not

From the shallows of a small Wake Co. (c) reservoir, April.

*Closterium diana* Ehrenberg

From a Wake Co. (p) bog, spring.

*Closterium diana* var. *arcuatum* (Bréb.) Rabenhorst

In a sphagnum bog, Wake Co. (p), July.

*Closterium didymotocum* Corda

Throughout the state in the shallows of ponds, summer.

*Closterium eboracense* Turner

From one undated collection, Wake Co. (p).

*Closterium gracile* Brébisson

Wake Co. (p) (Poteat), Mitchell Co. (m) (Brown).

*Closterium jennerti* Ralfs

Wake Co., spring.

*Closterium kuetsingii* Brébisson

From several coastal plain swamps, late summer.

*Closterium leibleinii* Kuetsing

From several coastal plain swamps, late summer. Also from Mitchell Co. (m) (Brown).

*Closterium lineatum* Ehrenberg

Wake Co. (p) (Poteat) and Mitchell Co. (m) (Brown).

*Closterium lunula* Ehrenberg

From a Wake Co. (p) collection, spring.

*Closterium moniliferum* Ehrenberg

Wake Co. (p) (Poteat) and Mitchell Co. (m) (Brown).

*Closterium nasatum* Nordstedt

Wake Co. Poteat says that this differs somewhat from the typical form.

*Closterium navicula* (Bréb.) Luetkmüller

Among other species of desmids in a Wake Co. (p) pond, August.

*Closterium obtusum* Brébisson

Wake Co. (p) (Poteat).

*Closterium peracerosum* Gay

Onslow Co. (c), August.

*Closterium peracerosum* var. *elegans* G. S. West

From an unmarked collection (Wake Co.?).

*Closterium pritchardianum* Archer

From the shallows of Boone's Pond, Wake Co. (p), August.

*Closterium rostratum* Ehrenberg

Wake Co. (p) (Poteat) and Mitchell Co. (m) (Brown).

*Closterium setaceum* Ehrenberg

From three coastal plain ponds, Bladen and Cumberland Cos., spring.

*Closterium sigmoideum* (Lagerh.) Nordstedt

From one Wake Co. (p) collection, spring.

*Closterium striolatum* Ehrenberg

Apparently widespread. Wake Co. (p) (Poteat), Anson (p) and Avery (m) Cos. (Whitford).

*Closterium tumidum* Johnson

From an old collection. (Wake Co.?).

*Penium closterioides* Ralfs

Collected near Wake Forest by Poteat, Wake Co. (p).

*Penium crassa* De Bary

Reported only by Poteat, Wake Co. (p).

*Penium lamellosum* Brébisson

Reported by Poteat, Wake Co. (p).

*Penium margaritaceum* (Ehr.) Brébisson

From one pond in each section of the state, Wake Co. (p) (Poteat), Craven (c) and Macon (m) Cos. (Whitford), summer.

*Penium spirostriolatum* Barker

Wake Co. (p), February, Cumberland Co. (c), May.

*Pleurotaenium coronatum* (Bréb.) Rabenhorst

In a ditch near Lake Mattamuskeet; Hyde Co. (c), May.

*Pleurotaenium ehrenbergii* (Bréb.) De Bary

From piedmont and coastal plain ponds, summer.

*Pleurotaenium ehrenbergii* var. *elongum* W. West

Cottonade Pond, Cumberland Co. (c), May.

*Pleurotaenium maximum* (Reinsch) Lundell

From ponds, Avery Co. (m), June, Wake Co. (p), October.

*Pleurotaenium minutum* f. *major* Lundell

In the plankton, Holly Smith Pond, Bladen Co. (c), June.

*Pleurotaenium minutum* var. *elongatum* W. & G. S. West

In the plankton, Holly Smith Pond, Bladen Co. (c), June.

*Pleurotaenium nodosum* (Bailey) Lundell

From rain pools in the coastal plain, Bladen, Craven, Harnett, Wake Cos., spring.

*Pleurotaenium subcornulatum* var. *detum* (Turner) W. & G. S. West

Cells united into short filaments.

Apparently widespread; in all sections of the state, spring and summer.

*Pleurotaenium trabecula* (Ehr.) Naegeli

From two coastal plain counties, Bladen and Wilson, (Whitford), also Wake Co. (p) (Poteat).

*Pleurotaenium trabecula* f. *clavata* (Kuetz.) W. & G. S. West

From the plankton of one mountain pond, Avery Co., June.

*Pleurotaenium trabecula* var. *rectum* (Delp.) W. West

Widespread in the coastal plain, spring.

*Pleurotaenium tridentulum* var. *capitatum* West

In the plankton of Holly Smith Pond, Bladen Co. (c), May.

*Pleurotaenium trochiscum* var. *tuberculatum* W. & G. S. West

From two cypress ponds in Craven Co. (c), spring.

*Docidium baculum* Brébisson

From an undated collection at Raleigh, Wake Co. (p).

*Docidium crenulatum* Rabenhorst

Reported by Poteat, Wake Co.

*Docidium undulatum* Bailey

From several coastal plain ponds, spring and summer.

*Triploceras gracile* Bailey

Generally distributed in coastal plain waters, spring and summer.

*Triploceras verticillatum* Bailey

In the coastal plain only, spring and summer.

*Tetmemorus brebissonii* (Menegh.) Ralfs

Throughout the state, spring.

*Tetmemorus brebissonii* var. *minor* (Menegh.) Ralfs

From one Wake Co. (p) bog, July.

*Tetmemorus laevis* (Kuetz.) Ralfs

From one collection in each of the three sections of the state, Cumberland (c), Wake (p) (Poteat) and Madison (m) Cos., spring.

*Euastrum affine* Ralfs

Among sphagnum in coastal plain bogs, spring.

*Euastrum ampullaceum* Hassall

From one ditch, Beaufort Co. (c), December.

*Euastrum ansatum* Ralfs

From several Wake Co. (p) collections (Poteat, Whitford).

*Euastrum bidentatum* Naegeli

From coastal plain pools and swamps, throughout the year.

*Euastrum binale* Ralfs

Reported by Poteat only, Wake Co. (p).

*Euastrum binale* var. *elobatum* (Turp.) Ehrenberg

From Anson Co. (p), April.

*Euastrum elegans* Kuetzing

Wake Co. (p) (Poteat) and Mitchell Co. (m) (Brown).

*Euastrum humerosum* Ralfs

From one Onslow Co. (c) pond, December.

*Euastrum inermis* Lundell

Poteat, who reports this species, says that it does not quite agree with Wolle's figure.

*Euastrum oblongum* Ralfs

Reported by Poteat only, Wake Co. (p).

*Euastrum pinnatum* Ralfs

Wake Co. (p) (Poteat) and Mitchell Co. (m) (Brown).

*Euastrum sinuosum* var. *reductum* W. & G. S. West

From two coastal plain ponds, Cumberland and Moore Cos., May.

*Euastrum verrucosum* Wolle

From several coastal plain ponds, spring (Whitford). Also Wake Co. (Poteat).

*Euastrum verrucosum* var. *alatum* Wolle

Wake Co. (p) (Poteat) and Mitchell Co. (m) (Brown).

*Euastrum verrucosum* var. *reductum* Nordstedt

Wake Co. (p) (Poteat) and Mitchell Co. (m) (Brown).

*Cosmarium asphaerosporum* var. *strigosum* Nordstedt

From a Wilson Co. (c) swamp, September.

*Cosmarium binum* Nordstedt

Swamp, Wilson Co. (c), September.

*Cosmarium botrytis* Meneghini

Wake Co. (p) (Poteat), Mitchell Co. (m) (Brown).

*Cosmarium botrytis* var. *gemmiferum* Meneghini

From Lake Raleigh, Wake Co. (p), spring.

*Cosmarium botrytis* var. *tumidum* Wolle

Wake Co. (p) (Poteat).

*Cosmarium braunii* f. *major* Reinsch

Wake Co. (p) (Poteat).

*Cosmarium connatus* Kirchner

Wake Co. (p) (Poteat).

*Cosmarium connatus* var. *minor* Nordstedt

Wake Co. (p) (Poteat).

*Cosmarium costatum* Nordstedt

Mitchell Co. (m) (Brown).

*Cosmarium cucumis* Corda

Wake Co. (p) (Poteat), Mitchell Co. (m) (Brown).

*Cosmarium elegantissimum* var. *simplicis* (Lund.) W. & G. S. West

In seepage water on rocks and soil. Madison (m) and Wake (p) Cos., spring.

*Cosmarium galeritum* Nordstedt

From one unmarked collection.

*Cosmarium hammeri* Reinsch

Swamp, Wilson Co. (c), September.

*Cosmarium minutus* Kirchner

Wake Co. (p) (Poteat).

*Cosmarium moniliforme* (Turp.) Ralfs

From the plankton of coastal plain ponds, Bladen, Carteret, Cumberland Cos., spring.

*Cosmarium notabile* Brébisson

Wake Co. (p) (Poteat).

*Cosmarium pathodes* var. *amoebum* W. West

Not quite typical but apparently this variety. Wake Co. (p), spring.

*Cosmarium orbiculum* Ralfs

Wake Co. (p) (Poteat).

*Cosmarium ovale* Ralfs

Avery Co. (m) (Whitford), Mitchell Co. (m) (Brown), Wake Co. (p) (Poteat).

*Cosmarium portianum* Archer

Avery Co. (m) (Whitford), Mitchell Co. (m) (Brown), Wake Co. (p) (Poteat).

*Cosmarium pseudobroomsi* Wolle

Wake Co. (p) (Poteat).

*Cosmarium pseudoconnatum* Nordstedt

Wake Co. (p), spring and summer.

*Cosmarium punctulatum* Brébisson

Wake Co. (p) (Poteat).

*Cosmarium pyramidatum* Brébisson

Wake Co. (p) (Poteat), Mitchell Co. (m) (Brown).

*Cosmarium schleipackeanum* Grunow

Wake Co. (p) (Poteat).

*Cosmarium speciosum* Lundell

Wake Co. (p) (Poteat).

*Cosmarium thwaitesii* Ralfs

Wake Co. (p) (Poteat).

*Cosmarium undulatum* var. *crenulatum* Wolle

Wake Co. (p) (Poteat).

*Cosmocladium saxonicum* De Bary

The colonies break up and the connecting threads disappear in the preservative used (Transeau's solution). I believe this form has been collected a number of times but it has not been identified with certainty in my collections except from one pond in Wake Co. (c), spring.

*Micrasterias americana* Kuetzing

Wake Co. (p) (Poteat), Mitchell Co. (m) (Brown).

*Micrasterias apiculata* var. *fimbriata* f. *spinosa* (Biss.) W. & G. S. West

In a number of shallow ponds in the piedmont and coastal plain, spring.

*Micrasterias arcuata* var. *expansa* (Bailey) Nordstedt

The specimens of the above variety in my collection are somewhat simpler than those discussed and figured by Taylor from Newfoundland. In both apical and basal lobes there is a distinct resemblance to the next variety. Therefore, I agree with Nordstedt and Krieger in giving it merely varietal rank.

Rare in the plankton of one Cumberland Co. (c) pond, May.

*Micrasterias arcuata* var. *gracilis* (Bailey) W. & G. S. West

Rare in the plankton of two ponds, Bladen and Cumberland Cos. (c), May.

*Micrasterias conferta* Lundell

Wake Co. (p) (Poteat).

*Micrasterias crenata* Ralfs

Wake Co. (p) (Poteat).

*Micrasterias denticulata* Brébisson

From numerous collections throughout the state (Brown, Poteat, Whitford), spring.

*Micrasterias denticulata* var. *angulosa* (Hantsch.) W. & G. S. West

From a small pond in Carteret Co. (c), June.

*Micrasterias depauperata* var. *kitchellii* (Wolle) W. & G. S. West

From a small Carteret Co. (c) pond, June.

*Micrasterias decemdentata* Naegeli

Wake Co. (p) (Poteat).

*Micrasterias fimbriata* Ralfs

Wake Co. (p) (Poteat).

*Micrasterias fimbriata* var. *spinosa* Bissell

This variety which in my material sometimes has minute granulations as well as spines is recorded from an unknown locality in the coastal plain.

*Micrasterias floridensis* Salisbury

From the plankton of a Cumberland Co. (c) pond, May, 1935. The first collection since the description of the species.



*Micrasterias foliaceae* Bailey

This species has been collected for several years from one pond in the upper coastal plain (Wake County), in autumn only (October and November).

*Micrasterias furcata* Ralfs

Poteat lists this species with a question mark (Wake Co.?) but Brown reports it from Mitchell Co. (m).

*Micrasterias jenneri* Ralfs

From one unmarked collection (Wake Co.?).

*Micrasterias laticeps* Nordstedt

From five counties: Craven, Jones, Pamlico (c), Wake (p), Watauga (m), spring and summer.

*Micrasterias mahabuleshwariensis* var. *serrulata* (Wolle) G. M. Smith

From the plankton of a pond near Wilmington, New Hanover Co. (c), April.

*Micrasterias muricata* (Bailey) Ralfs

Common in the plankton of the coastal plain, spring and summer.

*Micrasterias pinnatifida* (Kuetz.) Ralfs

From two ponds, Macon Co. (m) and Wake Co. (p), spring.

*Micrasterias rabenhorstii* Kirchner

This species is tentatively listed by Poteat, Wake Co. (p).

*Micrasterias radiata* Hassall

This is our most widely distributed and most common species of *Micrasterias*.

*Micrasterias radiosa* Ralfs

From several ponds, Burke and Watauga (m), Wake (p), and Cumberland (c) Cos., summer.

*Micrasterias radiosa* var. *ornata* f. *elegantior* W. & G. S. West

From one cypress pond in Craven Co. (c), May.

*Micrasterias rotata* (Grev.) Ralfs

Reported by Brown, Poteat, and Whitford from numerous collections, spring and summer.

*Micrasterias thomasi* var. *notata* (Nordst.) Groenblad

From one ditch in Bladen Co. (c), May.

*Micrasterias torreyi* (Bailey) Ralfs

From ponds in the coastal plain only, spring and summer.

*Micrasterias truncata* (Corda) Brébisson

From the coastal plain only, throughout the year.

*Micrasterias truncata* var. *crenata* Reinsch

From two ponds, Beaufort and Craven Cos. (c), June and December.

*Xanthidium antilopaeum* (Bréb.) Kuetzing

The species is much less common than its varieties but typical cells occasionally are encountered.

Hyde Co. (c) May, Wake Co. (p) summer.

*Xanthidium antilopaeum* v. *laeve* (Bréb.) Kuetzing

From a Craven Co. (c) sphagnum bog, August.

*Xanthidium antilopaeum* var. *minneapolisense* Wolle

Rare in coastal plain plankton, spring.

*Xanthidium cristatum* var. *uncinatum* Brébisson

From small pools in the coastal plain, spring.

*Xanthidium fasciculatum* var. *hexagonum* Wolle

Reported only from Wake Forest, Wake Co. (p) by Poteat.

*Stauroastrum arctiscon* Brébisson

From several ponds in Wake Co. (c, p) (Poteat, Whitford).

*Stauroastrum botrophilum* Wolle

Wake Co. (p) (Poteat)

*Stauroastrum brachiatum* Ralfs

Common in Bladen Co. (c), bog pools, spring.

*Staurastrum brevispinum* Brébisson

From an unmarked coastal plain collection.

*Staurastrum cerastes* Lundell

From several coastal plain ponds, spring.

Reported from Wake Co. (p) by Poteat, November.

*Staurastrum clevei* (Witttr.) Roy & Bissell

From a Craven Co. (c) sphagnum bog, August.

*Staurastrum curvatum* W. West

Common in the plankton of an eastern bog lake, Bladen Co. (c) May.

*Staurastrum curvatum* var. *elongatum* G. M. Smith

With the species, Bladen Co. (c), May.

*Staurastrum cyrtocentrum* Brébisson

Wake Co. (p) (Poteat).

*Staurastrum dilatatum* Ehrenberg

Wake Co. (p) (Poteat).

*Staurastrum echinatum* Brébisson

Wake Co. (p) (Poteat).

*Staurastrum elongatum* var. *quadratum* Irène-Marie

The above variety recently described from Montreal seems identical with my material.

Rare in Suggs Mill Pond, Bladen Co. (c), May, 1935.

*Staurastrum forficulatum* f. *trigona* Wolle

In the plankton of Holly Smith Pond, Bladen Co. (c), September.

*Staurastrum hirsutum* (Ehr.) Brébisson

Wake Co. (c) (Poteat, Whitford), Mitchell Co. (m) (Brown).

*Staurastrum limneticum* var. *cornutum* G. M. Smith

From a pond 4,000 feet in elevation near Linville, Avery Co. (m), June.

*Staurastrum margaritaceum* var. *robustum* W. & G. S. West

From the plankton of one pond, Wake Co. (p), August.

*Staurastrum megacanthum* Lundell

In the plankton, Holly Smith Pond, Bladen Co. (c), September.

*Staurastrum monticulosum* Brébisson

From an unmarked collection.

*Staurastrum ophiura* var. *cambricum* (Lund.) W. & G. S. West

From a small Wake Co. (c) pool, June.

*Staurastrum orbiculare* Ralfs

Wake Co. (p) (Poteat).

*Staurastrum orbiculare* var. *depressum* Roy and Bissell

From a sphagnum swamp, Craven Co. (c), August.

*Staurastrum paradoxum* Meyen

From an unmarked collection.

*Staurastrum paradoxum* var. *cingulum* W. & G. S. West

From the plankton, Holly Smith Pond, Bladen Co. (c), September.

*Staurastrum paradoxum* var. *parvum* W. West

From the plankton of a Bladen Co. (c) pond, May.

*Staurastrum pygmaeum* f. *genuina* Brébisson

Wake Co. (p) (Poteat).

*Staurastrum pygmaeum* f. *truncata* Wolle

Wake Co. (p) (Poteat).

*Staurastrum pygmaeum* f. *rhomboides* Wolle

Wake Co. (p) (Poteat).

*Staurastrum quadricuspidatum* Turner

Rare in one Bladen Co. (c) pond, May.

*Staurastrum setigerum* Cleve

In a cypress pond, Onslow Co. (c), December.

*Staurostrum spiculiferum* G. M. Smith

Rare in the plankton, summer,

*Staurostrum spongiosum* Brébisson

Wake Co. (p) (Poteat).

*Staurostrum tohopkaligense* var. *brevispinum* G. M. Smith

From several Bladen Co. (c) ponds and pools, May.

*Staurostrum vestitum* Ralfs

Rare in the plankton of Holly Smith Pond, Bladen Co. (c), September.

*Arthrodesmus convergens* Ehrenberg

Rare in the plankton of one Wake Co. (p) pond, October.

*Arthrodesmus incus* var. *extensus* Andersson

From eastern bog lakes, Bladen Co. (c), spring.

*Onychonema laeve* var. *latum* W. & G. S. West

From Craven Co. (c) ponds, June and January.

*Onychonema laeve* var. *micranthum* W. & G. S. West

From ponds in the lower piedmont, spring, summer, and autumn.

*Sphaerosoma granulatum* Roy & Bissell

From the shallows of one Wake Co. (c) pond, late autumn.

*Sphaerosoma spinulosum* Delponte

Wake Co. (p) (Poteat).

*Spondylosium planum* (Wolle) W. & G. S. West

Occasional filaments have been seen among other filamentous algae in several Wake Co. (c, p) ponds, summer.

*Spondylosium pulchrum* (Bailey) Archer

Rare among other filamentous algae in the upper coastal plain, summer.

*Hyalotheca dissiliens* (Smith) Brébisson

Generally distributed but not so abundant when present as the varieties *tatrica* and *tridentula*. Reported also by Poteat.

*Hyalotheca dissiliens* f. *hians* Wolle

Among filamentous algae in a Carteret Co. (c) ditch, December.

*Hyalotheca dissiliens* f. *tridentula* Nordstedt

This form is widespread in the coastal plain, spring and summer.

*Hyalotheca dissiliens* var. *tatrica* Raciborski

Widespread among filamentous algae in the coastal plain.

*Hyalotheca mucosa* (Dillw.) Ehrenberg

General and common among other filamentous algae throughout the state. Present at all seasons.

*Hyalotheca neglecta* Raciborski

Rare in two ponds, Bladen and Johnston Cos. (c), February and May.

*Phymatodocis nordstedtiana* Wolle

Cells 58-63  $\mu$  wide, 43-47  $\mu$  long.

This rare desmid was collected in this country only twice in fifty years. Recently, however, it has been reported from Florida, and North and South Carolina. I believe the species to be rare but widely distributed in the acid waters of the Atlantic coastal plain. In this state it has been collected by the writer at four widely separated stations. Since it was first collected there in 1935, a careful search has always shown the alga to be present in a pond in southern Wake Co. It has also been found in plankton collections from Bladen and Harnett and New Hanover Cos., summer and autumn.

*Phymatodocis nordstedtiana* var. *minor* Borgesen

Cells 30-33  $\times$  30-33  $\mu$ . This variety was collected in the shallows of a cypress pond in Craven Co. (c) in May, 1939, and in the plankton of Holly Smith Pond, Bladen Co. in September and October, 1939. Recently reported from Georgia by Frohne.

*Desmidiium apogonum* Brébisson

Widely distributed in the coastal plain, among other filamentous algae in the shallows of ponds. Present at all seasons. Reported also by Poteat (Wake Co.).

*Desmidium baileyi* (Ralfs) Nordstedt

Our most common species of *Desmidium* especially in piedmont and coastal plain. Habitat same as that of preceding species. Present at all seasons but most abundant in spring. Also reported by Poteat.

*Desmidium coarctatum* Nordstedt

Among other filamentous algae and aquatic plants in a shallow cypress pond in southern Craven Co. (c), May.

*Desmidium cylindricum* Greville

This species can be confused with *D. grevillii* but typical specimens have been collected in Burke Co. (m), June.

*Desmidium grevillii* (Kuetz.) De Bary

Fairly common in ponds in piedmont and coastal plain, at all seasons.

*Desmidium quadratum* Nordstedt

From a sphagnum bog in Craven Co. (c), August.

*Desmidium swartzii* Agardh

This species has been collected in the coastal plain in winter and early spring but seems to be more widespread in the mountains. It is my opinion that it is a northern species while *D. baileyi* is a southern type. Also reported by Poteat (Wake Co.) and Brown (Mitchell Co.).

*Gymnozyga delicatissima* (Wolle) Nordstedt

Cells  $9.6 \times 9.6 \mu$ .

A few filaments of what seems to be the above species were found attached to other filamentous algae in a Craven Co. (c) pond, June, 1935.

*Gymnozyga moniliformis* Ehrenberg

Widespread in the piedmont and coastal plain. Never as abundant as some species of *Desmidium* but found in the same habitat. A few filaments of what appears to be a new form of this species were collected in the plankton of Holly Smith Pond, Bladen Co. (c), October, 1939.

*Gymnozyga moniliformis* var. *gracilescens* Nordstedt

This variety has been seen in collections from Craven Co. (c) in spring and autumn.

## CLASS CHAROPHYCEAE

## Order Charales

## Family Characeae

*Nitella flexilis* Agardh

Growing in shallow shaded rain-pools in Cameron Park, Wake Co. (p). Present during the cooler months. Fruiting in October.

*Nitella hyalina* (D. C.) Agardh

Collected by Stewart in the University Lake, Chapel Hill, Orange Co. (p). Present the year around but fruiting in spring.

*Nitella mucronata* A. Braun

Growing in muddy water up to one foot deep, Boone's Pond, Wake Co. (p). Fruiting in October.

*Nitella opaca* Agardh

In a shallow swampy stream north of Lake Raleigh, Wake Co. (p). Fruiting in May.

*Nitella* sp.

A species with a rather firm gelatinous envelope enclosing the sex organs is abundant during spring and summer in several coastal plain ponds. The species does not seem to be any of those reported from the United States. Wake Co. (c). Fruiting February to July and October.

*Chara* sp.

An undetermined species of *Chara* grew for nearly a year in a pond near Apex, Wake Co. (c). It has not been collected since. McAtee reports that *Chara* sp. was abundant in Currituck Sound in 1919. It has not been present recently, probably due to increased salinity of the water.

## EUGLENOPHYTA

## CLASS EUGLENOPHYCEAE

## Order Euglenales

## Family Euglenaceae

*Euglena acus* Ehrenberg

Frequent but not numerous in plankton collections from ponds and slow streams in the piedmont and coastal plain, spring and summer.

*Euglena acutissima* Lemmermann

Occasional cells are seen in plankton collections in summer.

*Euglena caudata* Huebner

From Yates Pond, Wake Co. (c) (Roller).

*Euglena deses* Ehrenberg

From temporary barnyard pools, summer.

*Euglena ehrenbergii* Klebs

Rare in Yates Pond, Wake Co. (c) (Roller).

*Euglena fusca* (Klebs) Lemmermann

One of the rarest species at Raleigh, Wake Co. (c) (Roller).

*Euglena gracilis* Klebs

Wake Co. (c) (Roller).

*Euglena intermedia* (Klebs) Schmitz

Pool, State College, Wake Co. (p) (Roller).

*Euglena oxyuris* Schmarda

From one eastern pond, Craven Co. (c), June.

*Euglena proxima* Dangeard

From a muddy roadside pool in the lower piedmont, Chatham Co. (p); also reported from Durham Co. (p) by Roller, autumn.

*Euglena rubra* Hardy

Common in the Davenport Pool, Wake Co. (p) (Roller).

*Euglena spirogyra* Ehrenberg

From warm stagnant pools, Craven and Lenoir Cos. (c), summer.

*Euglena splendens* Dangeard

From a Craven Co. (c) pond, June; also from Wake Co. (Roller).

*Euglena tripteris* (Duj.) Klebs

Rare in Yates Pond, Wake Co. (c) (Roller).

*Euglena viridis* Ehrenberg

Common in warm stagnant pools, spring and summer. Reported also by Roller.

*Leptocinclis texta* (Duj.) Lemmermann

Common in the plankton of a muddy pond in Wake Co., May.

*Phacus longicauda* (Ehr.) Dujardin

Frequent in plankton collections but individuals never numerous. Most abundant in spring.

*Phacus longicauda* var. *torta* Lemmermann

Occasional cells of this variety are seen in plankton collections.

*Phacus suecica* Lemmermann

From one eastern pond, Craven Co. (c), June.

*Phacus triquetus* Ehrenberg

From the plankton of a pond in Wake Co. (p), spring.

*Trachelomonas abrupta* var. *minor* Deflandre

From a temporary pasture pool at Raleigh, Wake Co. (p), April.

*Trachelomonas acanthos toma* (Stokes) Deflandre

Abundant in the plankton of a coastal plain pond, Bladen Co. (c), June.

*Trachelomonas armata* var. *spinosa* var. nov.

Lorica as in the type, except regularly covered with stout recurved spines which are shorter at the anterior end but increase in length and grade into the typical circle of long spines at the posterior end. Lorica  $27-30 \times 38-40 \mu$ , spines  $6-18 \mu$  in length. Fig. 5. Superficially the variety resembles *T. spinosa* but the shape of the lorica, the presence of a collar, the size, and the arrangement of the posterior spines place it definitely with *T. armata*.

A number of cells were seen in the plankton of a pond of dark water near Princeton, Wayne Co. (c), August, 1935.

*Trachelomonas armata* var. *steinii* Lemmermann

In the plankton of a Craven Co. (c), pool, June.

*Trachelomonas charkowiensis* var. *affinis* (Skv.) Deflandre

From a muddy slough near Neuse River in Lenoir Co. (c), June.

*Trachelomonas ensifera* (Daday) Deflandre

In the plankton of two piedmont ponds, Wake and Franklin Cos. (c), June.

A form has also been collected with a constriction just above the equatorial region and a sharply pointed posterior portion. Although it has some resemblance to *T. girardi-ana* it seems best to refer it to the above species.

*Trachelomonas euchlora* (Ehr.) Lemm. sec. Conrad

From Lake Raleigh, Wake Co. (p), April.

*Trachelomonas hispida* (Perty) Stein

From several ponds in Wake and Craven Cos. (p, c), spring.

*Trachelomonas hispida* var. *crenulatocollis* (Maskell) Skvortzow

In the plankton of a small reservoir in Wake Co. (c), May.

*Trachelomonas hispida* var. *duplex* Deflandre

In the plankton of a pond, Craven Co. (c), June.

*Trachelomonas horrida* Palmer

From the shallows of Lake Raleigh, Wake Co. (p) (Roller).

*Trachelomonas lemmermannii* var. *acuminata* Deflandre

In a pool in a ditch, Bladen Co. (c), May.

*Trachelomonas lolliensis* L. Whitford

From the plankton of a small reservoir near Apex, Wake Co. (c), May.

This species has recently been collected in a cypress swamp in Mississippi.

*Trachelomonas schauinslandii* Lemmermann

In a plankton collection from Lake Raleigh, Wake Co. (p), April.

*Trachelomonas volgensis* Lemmermann

Filtered from the water of Lake Raleigh, Wake Co. (p), April.

*Trachelomonas volvocina* Ehrenberg

Fairly common in piedmont and coastal plain ponds, spring.

*Eutreptia viridis* Perty

From Yates Pond, Wake Co. (c) (Roller).

## Family Colaciaceae

*Colacium vesiculosum* Ehrenberg

Attached to the eggs of a species of *Diaptomus* which were being carried by the adult crustacean, Boneyard Lake, Wake Co. (p), May.

## Family Astasiaceae

*Astasia klebsii* Lemmermann

Single colorless cells are frequently encountered in collections containing *Euglena* sp., spring and summer.

*Rhabdomonas costata* (Korshik.) E. G. Pringsheim

This colorless flagellate is fairly common in collections from stagnant pools in the lower piedmont and coastal plain, spring and summer.

*Menoidium incurvum* (Fres.) Klebs

From a ditch near Southport, Brunswick Co. (c), February.

## Family Peranemaceae

*Peranema trichophorum* (Ehr.) Stein

Occasional colorless cells are sometimes seen in collections containing *Euglena*, spring and summer.

## Class Chloromonadineae

*Gonyostomum semen* Diesing

Cells  $33-40 \times 51-55 \mu$ .

This rarely observed flagellate has been encountered in the plankton several times. It was abundant for several weeks in September, 1939, in the lily pond in Pullen Park, Raleigh, Wake Co. (p).

The species is placed here for convenience, not because of close affinity with the Euglenophyceae.

## PYRROPHYTA

## CLASS CRYPTOPHYCEAE

## Order Cryptomonadales

## Family Cryptomonadaceae

*Cryptomonas erosa* Ehrenberg

Reported from ponds at Raleigh, Wake Co. (p) by Roller.

*Cryptomonas ovata* Ehrenberg

Wake Co. (p), Roller.

*Cryptomonas* spp.

Several species of *Cryptomonas* have been seen in collections throughout the eastern half of the state. None seemed to be either of the preceding two species. They are most frequent in small stagnant pools.

*Chilomonas paramecium* Ehrenberg

This colorless flagellate is frequently observed in the same habitat as species of *Cryptomonas*.

## CLASS DINOPHYCEAE

## Order Gymnodiniales

## Family Glenodiniaceae

*Glenodinium* spp.

Several species of *Glenodinium* have been seen at times in the plankton of piedmont ponds, but none have been identified as to species.

## Family Peridiniaceae

*Peridinium cinctum* Ehrenberg

Frequently present but never abundant in plankton collections from piedmont and coastal plain, spring.

*Peridinium tabulatum* (Ehr.) Claparède and Lachmann

Reported from three Wake Co. (p) ponds by Roller.

*Peridinium volsi* Lemmermann

From the plankton of two coastal plain ponds, Cumberland and Onslow Cos., December and May.

*Peridinium westii* Lemmermann

Cells nearly spherical but slightly flattened dorso-ventrally. Without an apex. Transverse furrow nearly in middle of cell; longitudinal furrow extending anteriorly slightly or not at all. The plates are thick and ornamented with stout ridges running in an anterior-posterior direction with smaller reticulations and punctations between. The epivalve has 14 plates; 7 precingulars, 1 rhomboidal, 5 intercalary, and one apical plate. There is frequently a thin ventral plate. Length  $70-76 \mu$ , width  $67-70 \mu$ . Figs. 9-12.

Although not listed by Eddy (1930), I believe the form deserves specific rank. The cell shape and arrangement of plates is similar to that in *P. volzi* but the very slight anterior extension of the longitudinal furrow, the large rhomboidal plate, and the prominent ridges easily distinguish it from other species.

Common and at times abundant in coastal plain plankton. Bladen, Harnett, and Wake Cos., spring and autumn.

*Peridinium wisconsinense* Eddy

Widespread and locally abundant in mountain and piedmont plankton collections. Occasionally seen in coastal plain collections, spring and autumn.

Family Ceratiaceae

*Ceratium carolinianum* (Bailey) comb. nov.

*Peridinium carolinianum* Bailey, Smithson. Contrib. Knowl. 2 (1851).

*Ceratium curvirostre* Huitfeldt-Kass, Vid. Skrif. math. nat. Kl. Christ. (1900). Bailey, who described and figured this species as *P. carolinianum*, says that it was abundant in the ditches near Charleston, S. C., during the winter of 1850. His paper was evidently not seen by Huitfeldt-Kass who also described it in 1900.

This species was long regarded as merely a variant or possibly a variety of *C. hirundinella* (O. F. M.) Schrank. Recent collections in the Atlantic coastal plain (Whitford, 1936; Prescott and Croasdale, 1938), however, have definitely established the validity of the species. In North Carolina it has been collected several times in the same pond with typical cells of *C. hirundinella*. There were absolutely no intergrading forms. Fig. 8. The species is common and frequently abundant in the plankton of eastern ponds. Found in the coastal plain only, at all seasons but most abundant in spring.

*Ceratium hirundinella* (O. F. M.) Schrank

In the plankton throughout the state but not common in the coastal plain. Frequently abundant in piedmont ponds during the cooler months. This species is a typical piedmont and mountain species and is most abundant in neutral or alkaline waters while *C. carolinianum* seems to be confined to acid waters.

*Ceratium hirundinella* form *piburgense* Zederbauer

This form has been seen several times in piedmont collections, spring.

CHRYSTOPHYTA

CLASS XANTHOPHYCEAE

Order Rhizochloridales

Family Stipitococcaceae

*Stipitococcus urceolatus* W. and G. S. West

A species of *Stipitococcus*, probably the one given above, is sometimes abundant on filaments of *Oedogonium* in swampy pools in Wake Co. (p), in summer.

Family Chlorosaccaceae

*Chlorosaccus fluidus* Luther

Cells  $8-9 \times 10 \mu$ , colonies up to 3 mm. in diameter. Attached to grass stems in a small pool in Johnston Co. (c), April.

Order Heterococcales

Family Botryococcaceae

*Botryococcus braunii* Kuetsing

General throughout the state. Once or twice it was abundant in the plankton of small pools at Raleigh. At all seasons but most abundant in spring.

*Botryococcus sudeticus* Lemmermann

Not as common as the preceding species but frequently seen in plankton collections in spring.



Family Chlorotheciaceae

*Parthenella planktonica* G. M. Smith

A species occasionally found, epiphytic on *Hyalotheca mucosa*, seems to be the above species rather than *P. hyalothecae*. From the piedmont only, summer.

Family Ophiocytaceae

*Ophiocytium capitatum* Wolle

Widespread, especially in the coastal plain, but never abundant. Among filamentous algae in spring.

*Ophiocytium capitatum* var. *longispina* (Moewus) Lemmermann

This variety is nearly as common as the species and is found in the same localities and habitat. Spring.

*Ophiocytium cochleare* A. Braun

This species has been seen in only one collection from a canal at New Holland, Hyde Co. (c), May.

*Ophiocytium parvulum* (Perty) A. Braun

Among filamentous algae in two Wake Co. (p) ponds, spring.

Order Heterotrichales

Family Tribonemataceae

*Tribonema bombycinum* (Ag.) Derbes and Solier

Most frequent in temporary pools and slowly flowing clear brooks. Common in the piedmont but occasionally collected in the coastal plain, early spring

*Tribonema minus* (Wolle) Hazen

Not so common as the preceding species but found in the same habitats; early spring.

*Bumilleria sicula* Borzi

From several clear pools in sterile sandy soil near the coast, Brunswick and Carteret Cos. (c), winter.

Order Heterosiphonales

Family Botrydiaceae

*Botrydium granulatum* (L.) Greville

Widespread throughout the year on moist shady soil. Most common in autumn, winter, and spring.

CLASS CHRYSOPHYCEAE

Order Chrysomonadales

Suborder Chromulinineae

Family Chromulinaceae

*Chromulina* spp.

*Chromulina* has been collected a number of times, but the species have never been determined with any degree of certainty. An organism which was undoubtedly a species of *Chromulina* was abundant for a few days in a temporary pasture pool in southern Wake Co. (c), April. At another time a species was abundant in the brown scum on a swampy pool in the coastal plain (April).

Family Mallomonadaceae

*Mallomonas acaroides* Perty

This species has been seen only in coastal plain plankton. Bladen, Cumberland, Wake (3 stations), and Wayne Cos., spring and autumn.

*Mallomonas caudata* Conrad

Several species of *Mallomonas* are frequent in the plankton, especially from the coastal plain. The above species is one of the commonest; spring and summer.

*Mallomonas fastigata* Zacharias

From the plankton of a pond, Guilford Co. (p), May.

*Mallomonas freesei* Kent

This little known species was reported from Barnes, N. C., by Roller.

*Mallomonas producta* Iwanoff

Collected once in Dismal Swamp Canal, Camden Co. (c) and twice in eastern Wake Co. (c), spring and autumn.

*Chrysophaerella longispina* Lauterborn

This species seems to be rare but widespread in the plankton of the coastal plain. Several collections in each of the following counties: Cumberland, Harnett, and New Hanover, spring and autumn.

## Suborder Isochrysidineae

## Family Synuraceae

*Synura adamsii* G. M. Smith

Occasional typical colonies of the above species are seen in coastal plain collections, especially those from small shallow pools, early spring.

*Synura caroliniana* sp. nov.

Cells 6-10  $\times$  39-50  $\mu$ , elongate-ovoid, the posterior portion prolonged into a distinct stipe  $1\frac{1}{2}$  to 2 times the length of the anterior portion. The spines are very short and confined to the anterior half of the swollen portion of the cell. United into compact spherical (or ovoid) colonies 78 to 100  $\mu$  in diameter. Figs. 7-8.

Few-celled colonies somewhat resemble *S. adamsii* but the conic cells of this species are easily distinguished from the stipitate cells of *S. caroliniana*. The compact colonies are larger but otherwise resemble those of *S. uvella*.

The species is widespread and at times abundant in coastal plain plankton; at all seasons.

*Synura uvella* Ehrenberg

Widespread in the plankton throughout the state. Occasionally abundant in sunny pools in winter and early spring in the piedmont. Very rare during the warm months.

## Suborder Ochromonadineae

## Family Ochromonadaceae

*Uroglenopsis americana* (Calkins) Lemmermann

Apparently widespread at least in the piedmont and coastal plain in winter and early spring. The colonies and cells break up almost immediately in any preservative so that most collections are lost.

*Uroglena volvox* Ehrenberg

Rare in the plankton of small pools in late winter and early spring.

*Dinobryon bavaricum* Imhof

One of the most widespread species of *Dinobryon* in the state. Common in the plankton of the coastal plain and piedmont. It has not been collected as frequently in the mountains but this region has not been completely surveyed at all seasons. Most abundant in spring and autumn.

*Dinobryon campanulostipitum* Ahlstrom

From the plankton of coastal plain ponds, Craven, Cumberland, and Wayne Cos., summer.

*Dinobryon cylindricum* Imhof

General and at times abundant in the plankton especially in spring and autumn. Not yet seen in mountain collections but almost certainly occurring there.

*Dinobryon divergens* Imhof

Common in the plankton of the piedmont but apparently not nearly so abundant in the coastal plain, spring and autumn.

*Dinobryon eurytoma* (Stokes) Lemmermann

Epiphytic on filamentous algae in White Lake, Bladen Co. (c), August.

*Dinobryon pediforme* (Lemm.) Steinecke

Common in the plankton of the coastal plain, spring and summer.

*Dinobryon sertularia* Ehrenberg

Not so widespread as *D. cylindricum*, especially in the coastal plain but quite common in the piedmont during the cooler months.

*Dinobryon sociale* Ehrenberg

Rare in the plankton of the coastal plain, spring.

*Halobryon* sp.

A species of *Halobryon* has been collected a number of times in the coastal plain that differs in shape of lorica and form of colony from the well known species. It is epiphytic on filamentous algae in small pools and ditches in the coastal plain. Craven and Wake Cos., early spring.

Order Rhizochrysidales  
Family Rhizochrysidaceae

*Chrysamoeba radians* Klebs

Abundant in a small shady pool in Wake Co. (c), February.

*Lagynion macrotrachelum* (Stokes) Pascher

On *Oedogonium* sp. in a cypress pond in Craven Co. (c), May.

*Lagynion scherffellii* Pascher

Epiphytic on *Oedogonium* sp. in swampy pools in Wake Co. (c, p), autumn.

Order Chrysocapsales  
Family Chrysocapsaceae

*Phaeosphaera perforata* sp. nov.

Cells spherical or ovoid, 7.5–10.5  $\mu$  in diameter. Chromatophore a parietal band or cup, golden-brown in color, one or two in a cell. One or two contractile vacuoles frequently present. Food reserve colorless globules resembling oil.

The cells are scattered in a colorless gelatinous colony that is at first attached, saccate or cylindrical in shape, and perforated with numerous circular holes of various sizes. It may later expand into a loose reticulum of soft gelatinous strands.

The species is found attached to rocks in the rapids of cold brooks or floating in the pools below them. Figs. 13–14.

It has been collected for several years at three stations in Wake Co. (p), December to April. Also Lenoir Co. (c), April, May.

Almost certainly *Hydrurus foetidus* Kirch. will be found in the mountains. It has been collected in cold rocky torrents in the mountains of both the eastern and western United States, but so far has not been collected in North Carolina.

Class Bacillariophyceae

So little work has been done on the fresh-water diatoms of the state that no complete systematic arrangement will be given. Few species determinations have been made from my collections except for plankton forms.

Order Centrales

*Melosira* spp.

Several species are abundant in the plankton, winter and spring.

*Coccinodiscus* spp.

One or more species are at times abundant in the dark waters of the coastal plain.

Single discoid cells of another genus are occasionally seen in coastal plain plankton.

Order Pennales

*Rhizosolenia eriensis* H. L. Smith

Widespread but never abundant in the plankton of the lower piedmont and coastal plain, winter and spring.

*Tabellaria fenestrata* Kuetzing

Rare to abundant in piedmont and coastal plain collections, especially in spring. Sometimes in the plankton.

*Tabellaria flocculosa* (Roth) Kuetzing

Common in the plankton of piedmont and coastal plain, chiefly in spring.

*Fragilaria* spp.

Several ribbon-forming species are very abundant in sunny temporary pools in piedmont and coastal plain in spring.

*Synedra ulna* (Nitsch.) Ehrenberg

Very abundant in the bed of small streams, piedmont, winter and spring.

*Synedra* is our commonest plankton diatom. More than 90% of the volume of phytoplankton in winter may be *Synedra*.

*Asterionella formosa* Hassall

Abundant in the winter plankton of the piedmont. Found in the mountains in spring.

*Asterionella ralfsii* W. Smith

Abundant in the plankton of coastal plain ponds, winter and spring. Probably the common eastern species.

*Eunotia* spp.

Two or three solitary species are common in the ooze on the bottom of ponds.

*Cocconeis* sp.

A species is epiphytic on aquatics in Craven Co.

*Navicula* spp.

Many species are common in pools, ditches, and on wet soil at all seasons.

*Pinnularia viridis* (Nitsch.) Ehrenberg

Common in mats of *Vaucheria* in winter and spring.

Several other varieties and species are also present in our flora.

*Stauroneis* spp.

Not so common as *Navicula* but in the same habitats.

*Gyrosigma* spp.

Several species are common among filamentous green algae.

*Gomphonema acuminatum* Ehrenberg*Gomphonema dichotomum* Kuetzing

Both species common. Attached to filamentous green algae, spring.

*Cymbella* spp.

Attached and free-floating species are frequent in collections from ponds in the piedmont.

*Amphora* sp.

Occasional cells are seen in collections from streams.

*Surirella* spp.

Several species appear to be planktonic. Others inhabit the ooze on the bottom of ponds.

A species is common on the bottom of White Lake, Bladen Co. (c), in fifteen feet of water.

## CYANOPHYTA

## CLASS MYXOPHYCEAE

## Order Chroococcales

## Family Chroococcaceae

*Chroococcus decorticans* A. Braun

In running water on a wooden spillway, Haywood Co. (m), August (Leatherwood).

*Chroococcus dispersus* (V. Keissler) Lemmermann

In the plankton of a Wayne Co. (c) pond, June.

*Chroococcus limneticus* Lemmermann

Widespread but never abundant in the plankton of coastal plain ponds, spring.

*Chroococcus minutus* (Kuetz.) Naegeli

Among mosses in seepage on a rocky hillside, Wake Co. (p), March.

*Chroococcus multicoloratus* Wood

On a wooden spillway, Haywood Co. (m), August (Leatherwood).

*Chroococcus pallidus* Naegeli

From an old bottle, Wake Co. (p), March (Leatherwood).

*Chroococcus turgidus* (Kuetz.) Naegeli

Occasional colonies in the shallows of ponds and on wet soil and among mosses throughout the state, at all seasons (Hoyt, Philson, Whitford).

*Chroococcus varius* A. Braun

On a concrete dam, Haywood Co. (m), August (Leatherwood).

*Gleocapsa conglomerata* Kuetzing

Durham Co. (p) (Philson).

*Gleocapsa sparsa* Wood

Durham Co. (p) (Philson).

*Aphanocapsa delicatissima* W. and G. S. West

In the plankton of a muddy slough, Lenoir Co. (c), June.

*Aphanocapsa elachista* W. & G. S. West

In the plankton of Cottonade Pond, Cumberland Co. (c), May.

*Aphanocapsa grevillei* (Hass.) Rabenhorst

Durham Co. (p) (Philson).

*Aphanocapsa pulchra* (Kuetz.) Rabenhorst

From small shallow pools in Bladen and Craven Cos. (c), spring.

*Microcystis aeruginosa* Kuetzing

Widespread and at times abundant in the plankton, especially in spring and autumn.

Also reported as *M. flos-aquae* by Leatherwood.

*Merismopedia elegans* A. Braun

Scattered colonies, sometimes rather large, have been seen in collections from all regions of the state. Never abundant.

*Merismopedia glauca* (Ehr.) Naegeli

A few colonies have been collected in Bladen (c) and Wake (p) Cos., spring.

*Merismopedia maior* G. M. Smith

From one Wake Co. (p) pond, February.

*Merismopedia punctata* Meyen

Among filamentous algae in two ponds, Bladen and Hyde Cos. (c), May.

*Merismopedia tenuissima* Lemmermann

In the plankton of two Wake Co. (p) ponds, spring and autumn.

*Synechococcus aeruginosus* Naegeli

Among wet mosses where water seeps from a hillside, Wake Co. (p), March.

*Gleotheca membranacea* (Rab.) Bornet

From a wooden spillway, Haywood Co. (m), August (Leatherwood).

*Gleotheca rupestris* (Lyng.) Bornet

Among filamentous algae in ponds, Carteret and Cumberland Cos. (c), spring.

*Dactylococcopsis poleatii* Leatherwood

Cells  $1.5-2 \times 30-45 \mu$ . Attached to substrate.

This recently described species has been collected at one station only: on rock at Moore's Pond, Franklin Co. (p), spring (Leatherwood).

*Aphanothece conferta* Richter

Durham Co. (p) (Philson).

*Aphanothece pallida* (Kuetz.) Rabenhorst

Durham Co. (p) (Philson).

*Coelosphaerium naegelianum* Unger

Occasionally seen in the plankton of coastal plain and piedmont ponds, spring and autumn.

*Gomphosphaeria aponina* var. *delicatula* Virieux

From one bog pond in Craven Co. (c), June.

*Gomphosphaeria lacustris* Chodat

Apparently widespread in the coastal plain plankton, spring and summer.

Order Chamaesiphonales  
Family Chamaesiphonaceae

*Chamaesiphon incrustans* Grunow

Epiphytic on algae or moss scales in pools or aquaria. Wake Co. (p), winter and spring (Leatherwood, Whitford).

Order Hormogonales  
Suborder Homocystineae  
Family Oscillatoriaceae

*Spirulina laxa* G. M. Smith

Among filamentous algae in a brackish pool in Carteret Co. (c), and a pond in Wake Co. (p), autumn and winter.

*Spirulina major* Kuetzing

Rare among aquatics in one Wake Co. (p) pond, autumn.

*Spirulina princeps* (West and West) G. S. West

Rare in piedmont and coastal plain ponds, summer.

*Oscillatoria amoena* (Kuetz.) Gomont

On a concrete dam, Haywood Co. (m), August (Leatherwood).

*Oscillatoria amphibia* Agardh

From a Franklin Co. (p) pond, March (Leatherwood).

*Oscillatoria chalybea* Mertens

Forming a scum on a swampy pool, Wake Co. (p), March.

*Oscillatoria formosa* Bory

From a wooden spillway, Haywood Co. (m), August (Leatherwood).

*Oscillatoria geminata* Meneghini

From a brook, Wake Co. (p), March (Leatherwood).

*Oscillatoria lacustris* Geitler

In the shallows of a Harnett Co. (c) mill pond, May.

*Oscillatoria limosa* (A. G. Roth) Agardh

On soil and in slow streams.

Collected by von Schweinitz in Forsyth Co. (p) in 1812 (identified by Drouet); Haywood Co. (m) (Leatherwood); McDowell Co. (m) (Philson); and Wake Co. (p) (Whitford); spring and summer.

*Oscillatoria meslini* Frémy

On the bottom of a brook, Wake Co. (p), April.

*Oscillatoria princeps* J. P. Vaucher

Haywood Co. (m) (Philson).

*Oscillatoria prolifica* (Grev.) Gomont

On a wooden spillway, Haywood Co. (m), August (Leatherwood).

*Oscillatoria sancta* Kuetzing

Abundant among filamentous algae in coastal plain ponds in winter.

*Oscillatoria splendida* var. *uncinata* Setchell and Gardner

Franklin and Wake Cos. (p), spring (Leatherwood, Whitford).

*Oscillatoria subtilissima* Kuetzing

From a stream in northern Wake Co. (p), October (Leatherwood).

*Oscillatoria tenuis* Agardh

Franklin Co. (p) (Leatherwood); Durham Co. (p) (Philson); Jones and Carteret Cos. (c) (Whitford); spring and summer.

*Oscillatoria tenuis* var. *tergestina* Rabenhorst

From a pool on Shackleford Banks, Carteret Co. (c), March. (Collected by H. L. Blomquist).

*Phormidium angustissimum* W. and G. S. West

Durham Co. (p) (Philson).

*Phormidium autumnale* (Ag.) Gomont

Collected by von Schweinitz in 1812 "on staircase of barhouse" in Winston-Salem, Forsyth Co. (p) (identified by Drouet); common in greenhouses in Wake Co. (p) (Whitford).

*Phormidium corium* (Ag.) Gomont

Durham Co. (p) (Philson).

*Phormidium crouani* Gomont

Durham Co. (p) (Philson).

*Phormidium favosum* (Bory) Gom.

Forsyth, Wake, and Durham Cos. (p) (Drouet, Leatherwood, Philson).

*Phormidium inundatum* Kuetz

"Rare on stones in springs," Forsyth Co. (p) (Drouet).

*Phormidium reitsii* (Ag.) Gom.

Forsyth Co. (Drouet); Franklin Co. (Leatherwood); Durham Co. (p) (Philson).

*Phormidium subfuscum* Kuetzing

On a log in a creek, Wake Co. (p), March (Leatherwood).

*Phormidium uncinatum* (Ag.) Gom.

Forsyth Co. (p) (Drouet); Wake Co. (p) (Leatherwood, Whitford).

*Phormidium valderianum* (Delp.) Gomont

On a rock in a pond, Franklin Co. (p), March (Leatherwood).

*Lyngbya aerugineo-caerulea* (Kuetz.) Gomont

Durham Co. (p) (Philson).

*Lyngbya aestuarii* (Mertens) Liebman

Durham Co. (p) (Philson).

*Lyngbya birgei* G. M. Smith

On the surface of a stream, Wake Co. (p), April (Leatherwood).

*Lyngbya ferruginea* G. S. West

Among other filamentous algae, Wake Co. (p), March (Leatherwood).

*Lyngbya martensiana* Meneghini

From ponds in Franklin Co. (p) (Leatherwood); and Carteret and New Hanover Cos. (c) (Whitford); winter and spring.

*Lyngbya nana* Tilden

From an old bottle, Wake Co. (p), March (Leatherwood).

*Lyngbya ochracea* (Kuetz.) Thuret

Forsyth Co. (p) (Drouet).

*Porphyrosiphon notariisii* Kuetzing

On wet soil, Forsyth Co. (p) (Drouet); Wake Co. (p) (Leatherwood); spring.

*Microcoleus chthonoplastes* Thuret

From wet soil near the beach, Dare Co. (c) (Hoyt); from soil Wake Co. (p) (Leatherwood); winter and spring.

*Microcoleus lacustris* (Rab.) Farlow

From pools in Wake Co. (p), early spring (Leatherwood, Whitford).

*Microcoleus vaginatus* (Vaucher) Gomont

Apparently widespread on wet soil (Philson, Whitford).

*Symploca borealis* Rabenhorst

On damp soil in Wake Co. (p), April (Leatherwood).

*Schizothrix aikenensis* (Wolle) Philson

Durham Co. (p) (Philson).

*Schizothrix friesii* Gomont

Durham Co. (p) (Philson).

## Suborder Heterocystineae

## Family Nostocaceae

*Anabaena* Lemmermann

In the ~~season~~ of ponds, Wayne Co. (c), Wake Co. (p), summer.

*Anabaena asollae* Strasburger

Apparently throughout the coastal plain in the leaves of *Azolla caroliniana*.

*Anabaena circinalis* Rabenhorst

Rare in the plankton of a pond near Princeton, Wayne Co. (c), June.

*Anabaena cycadeae* J. Reinke

From the roots of a cycad at Duke University, Durham Co. (p) (Philson).

*Anabaena flos-aquae* (Lyng.) Brébisson

Durham Co. (p) (Philson).

*Anabaena laxa* (Rab.) A. Braun

McDowell Co. (m) (Philson).

*Anabaena oscillarioides* Bory

Forming gelatinous masses in shallow pools, Wake Co. (p), spring.

*Anabaena parva* Philson

Wake Co. (p), March (Leatherwood).

*Anabaena torulosa* (Carmichael) Lagerheim

Durham Co. (p) (Philson).

*Nostoc commune* Vaucher

On wet soil and rocks near seepages throughout the piedmont. Most abundant in spring and autumn (Drouet, Whitford, Curtis).

*Nostoc microscopicum* Carmichael

On wet rocks at 5,000 feet elevation, Swain Co. (m), June.

*Nostoc muscorum* Agardh

Wake Co. (p) (Leatherwood).

*Nostoc paludosum* Kuetzing

Durham Co. (p) (Philson); Wake Co. (p) (Leatherwood).

*Nostoc parmelioides* Kuetzing

In streams and pools, Carteret (c) and Wake (p) Cos., spring.

*Nostoc peltigerae* Letellier

The algal symbiont in a lichen common on wet soil in Wake Co. (p).

*Nostoc punctiforme* (Kuetz.) Hariot

Durham Co. (p) (Philson).

*Nostoc sphaericum* Vaucher

On a submerged log, Wake Co. (p) (Leatherwood).

*Aphanizomenon flos-aquae* (L.) Ralfs

Occasional in the plankton of coastal plain ponds, summer.

*Cylindrospermum alatosporum* F. E. Fritsch

Durham Co. (p) (Philson).

*Cylindrospermum catenatum* Ralfs

On a wooden spillway in Haywood Co. (m), August (Leatherwood).

*Cylindrospermum minutum* Wood

Wake Co. (p), October (Leatherwood).

*Cylindrospermum muscicola* Kuetzing

Durham Co. (p) (Philson); Haywood (m) and Wake (p) Cos. (Leatherwood).

*Cylindrospermum stagnale* (Kuetz.) Bornet and Flahault

Haywood Co. (m), August (Leatherwood).

*Cylindrospermum trichospermum* Frémy

Durham and McDowell Cos. (p) (Philson).

*Nodularia harveyana* Thuret

Among other filamentous algae in New Hanover Co. (c) ponds, March.

*Nodularia spumigenia* Mertens

From a stagnant pond in Craven Co. (c), July.

## Family Scytonemaceae

*Scytonema carolinianum* Philson

Durham Co. (p) (Philson).



*Scytonema figuratum* Agardh

Buncombe Co. ? (m) (Drouet); Wake Co. (p), March (Whitford).

*Scytonema guyanense* (Mont.) Bornet and Flahault

Forayth Co. (p) (Drouet).

*Scytonema hoffmanii* Agardh

From a wet log, Wake Co. (p), November (Leatherwood).

*Scytonema insigne* W. and G. S. West

Durham Co. (p), Philson.

*Scytonema mirabile* (Dillw.) Bornet

On rocks in a stream, Wake Co. (p), March (Leatherwood).

*Tolypothrix rechingeri* (Wille) Geitler

Durham Co. (p) (Philson).

*Tolypothrix lanata* (Desv.) Wartmann

From a laboratory jar, Wake Co. (p) (Leatherwood).

*Tolypothrix penicillata* (Ag.) Thuret

On rock, Wake Co. (p), March (Leatherwood).

*Tolypothrix tenuis* Kuetzing

From a laboratory jar, Wake Co. (p) (Leatherwood).

*Plectonema battersii* Gomont

Reported by Hoyt as covering many square meters of wet soil on Ocracoke Island, Dare Co. (c), August.

*Microchaete terna* Thuret

With *Nostoc minutum* on wet rocks, Swain Co. (m), June.

## Family Stigonemataceae

*Stigonema hormoides* (Kuetz.) Bornet and Flahault

On wet rocks, Durham Co. (p) (Philson); Wake Co. (p), February (Whitford).

*Stigonema informe* Kuetzing

Durham Co. (p) (Philson).

*Stigonema mammosum* (Lyng.) Agardh

On wet rock, Wake Co. (p), autumn.

*Stigonema minutum* Hassall

On wet soil, Wake Co. (p), February.

*Stigonema minutum* var. *saxicola* (Naegeli) Bornet and Flahault.

On wet rock, Wake Co. (p), March (Leatherwood).

*Stigonema panniforme* (C. A. Agardh) Kirchner

Durham Co. (p) (Philson).

*Stigonema turfatum* (Berk.) Cooke

Durham Co. (p) (Philson).

*Fisherella maior* Gomont

On stems in a temporary pool, Pender Co. (c), June.

*Hapalosiphon aureus* W. and G. S. West

On a wet log, Wake Co. (p), November (Leatherwood).

*Hapalosiphon fontinalis* (Ag.) Bornet

On wood or among aquatic plants in the shallows of ponds and lakes, Bladen (c), Craven (c), Wake (p) Cos., at all seasons (Whitford); Haywood Co. (m) (Leatherwood).

*Hapalosiphon hibernicus* W. and G. A. West

In bog pools, Craven (c) and Wake (p) Cos., at all seasons.

*Hapalosiphon welwitschii* W. and G. S. West

Durham Co. (p) (Philson).

## Family Rivulariaceae

*Calothrix braunii* Bornet and Flahault

Durham Co. (p) (Philson); Haywood Co. (m), August (Leatherwood).

*Calothrix fusca* Bornet and Flahault

From stagnant pools, Wake Co. (p), spring.

*Calothrix juliana* (Menegh.) Bornet and Flahault

With *C. braunii* on a concrete dam, Haywood Co., August (Leatherwood).

*Calothrix scytonemicola* Tilden

In a pond, Wake Co. (p) April (Leatherwood).

*Dichothrix* sp.

This species is the algal symbiont in the rare lichen *Lichina confinis*, which is abundant on granite rock near seepages in northern Wake Co. (p).

*Rivularia globiceps* G. S. West

On aquatics in a pond in southern Wake Co. (c), May.

*Gleotrichia echinula* (J. E. Smith) P. Richter

On grass stems in a swampy pool, Wilson Co. (c), September. A species, probably the same, has been collected a number of times in Wake Co. (p) in spring.

## RHODOPHYTA

## CLASS RHODOPHYCEAE

## Subclass Florideae

## Order Nemalionales

## Family Batrachospermaceae

*Batrachospermum moniliforme* Roth

This species is widespread in brooks and small streams in winter and early spring. First reported by Curtis (1867).

*Batrachospermum pyramidale*? Sirodot

A species apparently the above has been collected in Johnston Co. (c), April.

*Batrachospermum vagum* var. *keratophyllum* Bory

Common in spring in the shallows of White Lake, Bladen Co. (c). A species of *Batrachospermum*, probably the above one, grows perennially in the *Chantransia* stage in the swamp on the south side of White Lake. This is probably due, as pointed out by Fritsch,<sup>7</sup> to the low light intensity.

## Family Lemnaceae

*Lemanea australis* Atkinson

This species is probably the common one throughout the piedmont and coastal plain. It was described from a collection made in Orange Co. by Atkinson, and has been found in streams in most of the southeastern states. Orange Co. (p) (Atkinson); Montgomery (p) and Wake (c) Cos. (Whitford). Winter, spring, and early summer.

*Lemanea fucina* (Bory) Atkinson

From streams in Montgomery (p), Transylvania (m), and Wake (c) Cos., April to June.

The piedmont and coastal plain collections also contained *L. australis*.<sup>8</sup>

*Lemanea fucina* var. *rigida* Atkinson

Collected by Thaxter at Oats Falls in 1896.

*Tuomeya fluviatilis* Harvey

This rare species was collected by H. L. Blomquist in a small stream near Clayton, Johnston Co. (c), in October. It is interesting that this species was reported by Curtis in 1867.

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RALEIGH, N. C.

<sup>7</sup> Fritsch, 1942 (p. 405).

<sup>8</sup> C. M. Palmer, who identified the species of *Lemanea* in my collections, believes *L. fucina* alone will be found at higher elevations, *L. australis* alone in the east, and the two species together at intermediate elevations.

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## EXPLANATION OF PLATE 21

All figures were drawn with the aid of a camera lucida.

Fig. 1. *Chlamydomonas fenestrata* sp. nov.  $\times 2350$ .

Fig. 2. *Chlamydomonas patellaria* sp. nov.  $\times 1000$ .

Fig. 3. *Tomaculum catenatum* gen. & sp. nov.  $\times 140$ . Colony showing arrangement of cells and gelatin sheath.

Fig. 4. *Tomaculum catenatum*  $\times 750$ . Cell showing chloroplasts and connecting strands.

Fig. 5. *Trachelomonas armata* var. *spinosa* var. nov.  $\times 475$ . External view of lorica.

Fig. 6. *Synura caroliniana* sp. nov.  $\times 390$ . Typical colony.

Fig. 7. *Synura caroliniana*  $\times 1000$ . Single cell.

Fig. 8. *Ceratium carolinianum* (Bailey) nov. comb.  $\times 280$ . Dorsal view of cell in outline.

Fig. 9. *Peridinium westii* Lemmermann  $\times 440$ . Ventral view.

Fig. 10. *Peridinium westii*.  $\times 440$ . Dorsal view.

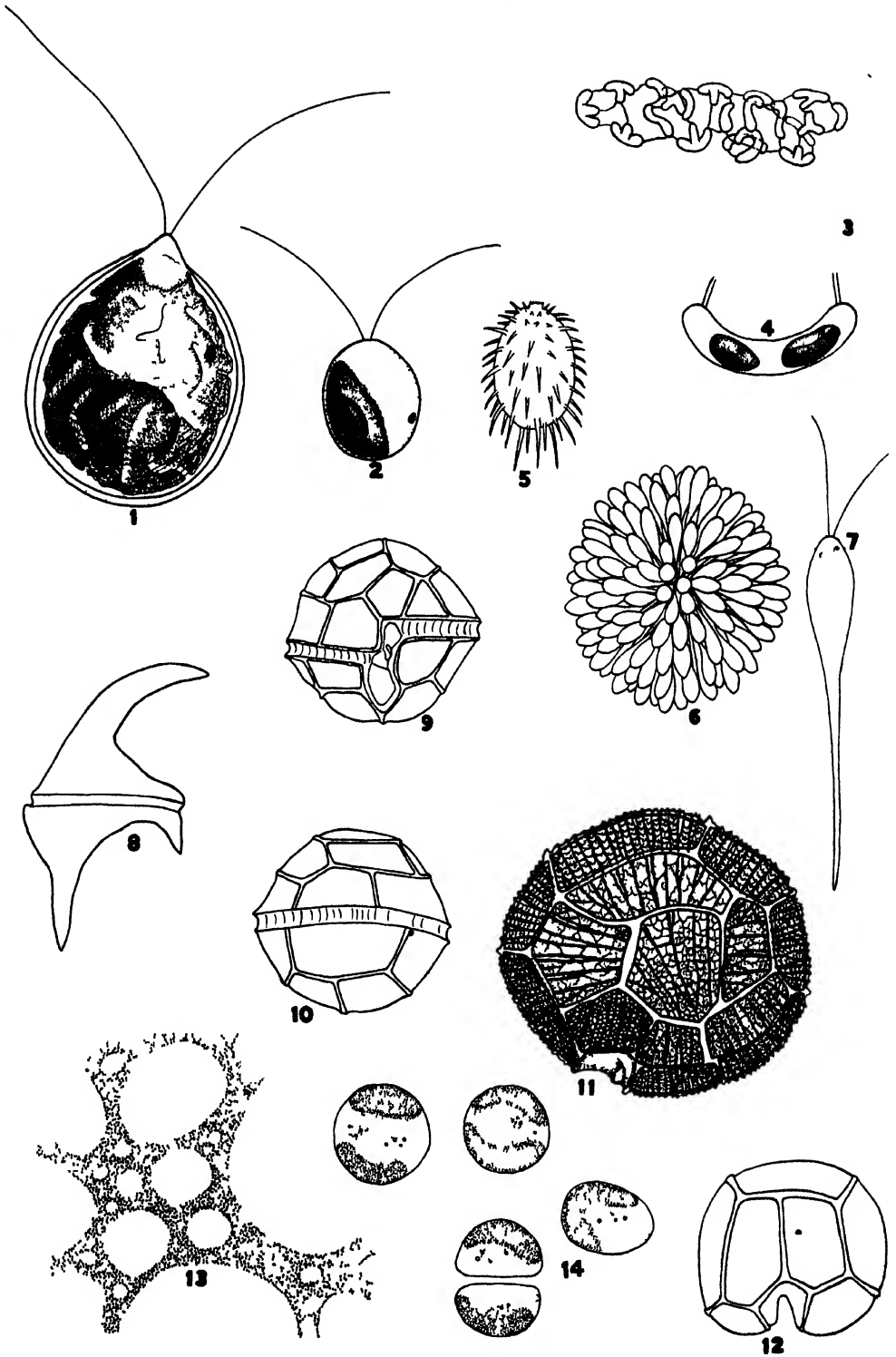
Fig. 11. *Peridinium westii*.  $\times 700$ . Apical view showing characteristic ornamentation.

Fig. 12. *Peridinium westii*.  $\times 440$ . Antapical view.

Fig. 13. *Phaeosphaera perforata* sp. nov.  $\times 30$ . Bit of colony showing arrangement of cells and characteristic perforations

Fig. 14. *Phaeosphaera perforata*  $\times 1390$ . Typical cells showing chromatophore, food granules, and contractile vacuole.

PLATE 21





# THE APHID GENUS *DREPANAPHIS* DEL GUERCIO<sup>1</sup>

By CLYDE F. SMITH AND GEORGE F. KNOWLTON<sup>2</sup>

## PLATE 22

In 1941, Smith (Jour. Elisha Mitchell Sci. Soc. **57**: 226-242) called attention to the presence of undescribed species of *Drepanaphis* in Utah and Idaho. Since that time, the writers have paid particular attention to the living material as well as preparing a large series of mounted specimens from these states. The present paper describes two species as new and gives a key to the described species in the United States, with notes on others which have been described in the genus *Drepanaphis*.

Takahashi described two species of aphids under the names *Drepanaphis tokyoensis* (Formosa Dept. Agr. Gov't. Res. Inst. Rept. **4**: 66, 1923), and *Drepanaphis sauteri* (Formosa Dept. Agr. Gov't. Res. Inst. Rept. **22**: 8, 1927). The writers have not seen specimens of the above species but judging from the descriptions they are quite distinct from any of the known species of North American *Drepanaphis*.

Davis (Ent. News **21** (5): 195, 1910) described a species under the name *Drepanaphis* ? *minutus* Davis, which Hottes and Frison in 1931 (Illinois Natural History Survey Bull. **19**, Art. III, p. 267) made the genotype of their genus *Shenahweum*.

### *Drepanaphis* Del Guercio

#### Key to alate vivipara

1. Only the tips of the wing veins and base of radius marked with fuscous ..... 4  
Wing veins, especially radius and medius, broadly bordered with fuscous for their entire length (this is seen most clearly through the low power of the microscope) .. 2
- 2 (1). Abdominal tubercles I and II absent or inconspicuous, III large and conspicuous (Fig. 17)..... *keshenae* Granovsky  
Abdominal tubercles I and II conspicuous, longer than width at base..... 3
- 3 (2). Abdominal tubercle I long and finger-like, practically as long as III and distinctly longer than II (Fig. 8); fore femora dusky..... *acerifoliae* Thomas  
Abdominal tubercle I never as long as III and usually subequal to II (Fig. 13); fore femora pale..... *parvus* Smith
- 4 (1). Tubercle I conspicuous; dorsum of abdomen bearing 3 or more pairs of dorsal tubercles which are conspicuous and usually distinctly longer than width at base (Figs. 1, 7, 9, 13, 16)..... 9  
Tubercle I inconspicuous; dorsum of abdomen usually bearing only 1 pair of dorsal tubercles which is conspicuous and distinctly longer than width at base (occasionally 2 additional small pairs may be present) (Figs. 4, 11, 14, 17, 18).... 5
- 5 (4). Distal one-third of cornicle dark, concolorous with tubercle III which is dark... 7  
Distal one-fifth or more of cornicle pale, usually distinctly lighter than tubercle III; however, tubercle III may be pale, in which case all of the cornicle is pale... 6

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<sup>2</sup> Associate Entomologists.



- 6 (5). Tubercle III distinctly longer than base of antennal VI.....*kansensis* Smith  
 Tubercle III subequal to base of antennal VI.....*utahensis* K. and S. n. sp.
- 7 (5). Antennal II lighter than antennal I, tubercle III or cornicle; either the distal end or all of the hind femora dusky..... 8  
 Antennal II dark, as dark as antennal I, tubercle III or cornicle; all of hind femora pale.....*spicatum* Smith
- 8 (7). Proximal two-thirds of hind femora light, contrasting with the dark distal end; upper edge of front femora dark, rest of front femora and all of middle femora light; antennal III usually with 12 to 15 sensoria.....*spicatum* Smith  
 All of hind femora dusky to fuscous, distal and proximal ends not distinctly contrasting; fore femora dark on upper and lower edges, occasionally dark all over; middle femora often dusky; antennal III usually with 10 to 12 sensoria. On *Aesculus* spp.....*monelli* Davis
- 9 (4). Tubercles I and/or II smaller or more finger-like than III; tubercle III dusky to dark..... 10  
 Tubercles I, II, and III all approximately the same length, shape and size (Fig. 1); tubercle III pale.....*granovskyi* S. and K. n. sp.
- 10 (9). Tubercles I and II approximately the same length; tubercle II distinctly smaller (shorter) than III; large sensorium on antennal VI with 4 accessory sensoria (Fig. 10)..... 11  
 Tubercles II and III approximately the same length; tubercle I usually distinctly smaller than II; large sensorium on antennal VI with 5 to 7 accessory sensoria (Fig. 12).....*sabrinæ* Miller
- 11(10). Fore femora and basal portion of fore and middle tibiae pale; middle and hind femora and base of hind tibiae may be slightly obfuscated in some specimens.. 12  
 All femora and basal portion of all tibiae dusky to fuscous; middle femora often only slightly obfuscated.....*carolinensis* Smith
- 12(11). Antennal II slightly lighter than I, tubercle III, or basal portion of cornicle; cornicle not unicolorous if any of it is dusky or dark. (If antennal II appears practically concolorous with I, II is not distinctly darker than hind femora and hind femora is dark)..... 13  
 Antennal II dark, concolorous with antennal I, tubercle III, and basal portion of cornicle; cornicle fuscous and unicolorous, distal end nearly as dark as the base; antennal II darker than hind femora; hind femora pale....*nigricans* Smith
- 13(12). Hind tibiae shorter than unguis; tubercle III usually longer than base of VI; tubercles I and II conspicuous.....*parvus* Smith  
 Hind tibiae longer than unguis; tubercle III subequal to base of VI; tubercles I and II usually absent or inconspicuous.....*utahensis* K. and S. n. sp.

*Drepanaphis acerifoliae* (Thomas)

(Fig. 8)

*Siphonophora acerifoliae* Thomas, Bull. Ill. State Lab. of Nat. Hist. I, No. 2: 4, 1878.

This species is quite common on silver maple (*Acer saccharinum*). It has been collected on this host in Utah at Bountiful, Logan, Provo, and Salt Lake City. It was also collected on *Acer platanoides* at Bountiful, Utah.

*Drepanaphis carolinensis* Smith

*Drepanaphis carolinensis* Smith, Jour. Elisha Mitchell Sci. Soc. 57(2): 231, 1941.

Additional material of this species collected on *Acer nigrum* at Columbus, Ohio, May 14, 1925 (Knowlton), and on *Acer saccharum* at Walsh, Minnesota, May 22, 1926, and St. Croix Falls, Wisconsin, May 29, 1926 (Knowlton), and on *Acer* sp. at Columbus, Ohio, May 24, 1937 (Smith).

*Drepanaphis granovskyi* S. & K. new species

(Figs. 1-3)

The striking characteristics of this species are the 3 pairs of pale tubercles which are quite small and about the same shape and length, and the light color of the body and all appendages.

*D. granovskyi* differs from *D. parvus* Smith in tubercles I and II being equal to III, not distinctly shorter; these tubercles being pale; and in not having the dark areas on each segment of the abdomen cephalad of the cornicles.

*Alate vivipara*: General body color pale whitish yellow, occasionally with a greenish tinge. Cleared specimens show the following characteristic colorations: light brown to slightly fuscous on antennal joints, unguis, thorax and tarsi; the rest of the body and appendages pale. Wings hyaline, veins without dusky borders except at very tips and at base of radius.

*Measurements*: Body 1.25 to 1.6 mm.; width of head through eyes .39 to .40; antennal III, .56 to .72; IV, .38 to .50; V, .38 to .51; VI, .09 to .13 plus .73 to .92; rostral IV plus V, .08 to .09; rostrum attaining second pair of coxae; hind tibiae .82 to 1.06; hind tarsi .11 to .12; cornicles .15 to .22; dorsal tubercle I, .08 to .10; II, .07 to .08; III, .07 to .08; IV, .01 to .03 mm.

Antennal III with 7 to 13 sensoria; of 53 antennae examined, 1 had 7, 10 had 8, 24 had 9, 10 had 10, 4 had 11, 3 had 12 and 1 had 13 sensoria. Antennal VI with 4 accessory sensoria around the primary sensorium. The abdominal tubercles are usually difficult to see due to their light color; tubercles I, II, and III are approximately equal in length and shape, I occasionally being slightly the longest; IV sometimes noticeable but never as long as I, II, or III.

*Type locality*: Liberty, Utah.

*Types*: Holotype in the United States National Museum; paracotypes and paratypes in the collections of the writers, the Utah Agricultural Experiment Station, Dr. A. A. Granovsky and in various other aphid collections.

*Collections*: Collected on *Acer grandidentatum* in Utah at Liberty, August 13, 1942, holotype slide (3 specimens) and 13 paratype slides (41 specimens); Beaver Canyon, July 10 1942, 1 paratype slide (7 specimens); Brigham Canyon, 3 paratype slides (32 specimens); Logan Canyon, October 4, 1929, 1 paratype slide (1 specimen), July 4, 1936, 2 paratype slides (4 specimens), June 20, 1942, 1 paratype slide (2 specimens); Mt. Nebo, July 12, 1942, 2 paratype slides (10 specimens); Rolapp, June 17, 1933, 1 paratype slide (9 specimens); Sardine Canyon, June 26, 1942, 1 paratype slide (2 specimens). This species has also been collected in Utah at Avon Canyon, Big Cottonwood Canyon, Bountiful, Eden, Mantua, Richmond, and Willow Creek. In Idaho it has been collected at Mink Creek and Strawberry Creek.

*Drepanaphis kansensis* Smith

*Drepanaphis kansensis* Smith, Jour. Elisha Mitchell Sci. Soc. 57 (2): 232, 1941.

The length of the cornicle is .20 to .26; of unguis 1.4 to 1.55 mm. In the original description, the length of the cornicle was accidentally omitted and the unguis was broken on all available material.

Since the preparation of the original description, the writers have seen material of the above species from *Acer saccharum*, Butler, Missouri, May 3, 1922 (A. C. Burrill); East Lansing, Michigan, July, 16, 1912 (C. P. Gillette); Sturgeon Bay, Wisconsin, July 29, 1927 (A. A. Granovsky); from *Acer nigrum*, Columbus, Ohio, May 13, 1925 (Knowlton).

*Drepanaphis parvus* Smith

*Drepanaphis parvus* Smith, Jour. Elisha Mitchell Sci. Soc. 57 (2): 237, 1941.

*Drepanaphis rubrum* Smith, Jour. Elisha Mitchell Sci. Soc. 57 (2): 238, 1941 (new synonymy).

After studying additional material from different localities, it appears that *Drepanaphis parvus* is a highly variable species and that *rubrum* should be placed as a synonym.

Material above 3,000 feet is similar to that originally described as *rubrum* and the specimens taken below 3,000 feet resemble *parvus*. However, there is considerable overlapping and the evidence indicates that we are dealing with only one species.

Since the original description of *parvus*, material has been studied from *Acer saccharum*, Sturgeon Bay, Wisconsin, July 29, 1927 (A. A. Granovsky). From *Acer rubrum*, Cooksburg, Pennsylvania, June 6, 1939 (R. H. Dodge), Savannah, Georgia, May 2, 1941, and numerous localities throughout North Carolina.

*Drepanaphis spicatum* Smith

(Figs. 15, 18)

*Drepanaphis spicatum* Smith, Jour. Elisha Mitchell Sci. Soc. 57 (2): 241, 1941.

A large series of specimens (40 slides including approximately 150 specimens) of *Drepanaphis* which are very similar to *spicatum* have been collected in Utah and Idaho on *Acer grandidentatum*. The material from Utah and Idaho differs from the material from North Carolina in tubercle III usually being larger (longer) and in having fewer and smaller dark areas around the hairs on the dorsum of the abdomen. However, these differences do not hold for all the specimens. Future study may prove that the material from Utah and Idaho belongs in a different species, but for the present the writers are considering that the eastern and western material in this group belongs to the same species.

Specimens have been collected on *Acer grandidentatum* in Utah at Big Cottonwood Canyon, Brigham Canyon, City Creek Canyon, Logan Canyon, Provo Canyon, Mantua, Mt. Nebo, Mt. Sterling, Smithfield Canyon, Strawberry Creek, and Weber Canyon (Devil's Slide). Specimens have been collected in Idaho at Franklin and Mink Creek (Dry Fork).

*Drepanaphis utahensis* K. & S. new species

(Figs. 4-6)

The striking characteristic of this species is the single pair of dorsal abdominal tubercles which are usually dark, short and broadly joined at the base.

*Drepanaphis utahensis* differs from *D. kansensis* Smith in the length of tubercle III, being subequal to base of antennal VI rather than distinctly longer; and in averaging more sensoria on antennal III.

*Alate vivipara*: General body color of living specimens whitish owing to a secretion of powdery material on the body; thorax relatively dark. Cleared specimens show the following characteristic colorations: light brown to fuscous on head, antennae I, II, and VI, and at antennal joints, thorax and tarsi (legs pale); large dark spots on the sides of the abdomen cephalad of the cornicles, tubercle III and cornicles (tip of cornicle may be light), the base of the cornicle usually being a shade lighter than tubercle III. The rest of body and appendages pale. Teneral specimens may have pale cornicles and tubercles. Wings hyaline, only the edges of stigmas, tips of veins and base of radius bordered with fuscous.

*Measurements*: Body, 1.5 to 2.0 mm.; width of head through eyes .45 to .56; antennal III, .86 to 1.01; IV, .56 to .82; V, .84 to .83; VI, .13 to .16 plus 1.05 to 1.46; rostral IV plus V, .10 to .11; rostrum attaining second pair of coxae; hind tibiae 1.32 to 1.74; hind tarsi .12 to .16; cornicles .25 to .30; dorsal tubercles I and II usually absent, occasionally .01 to .03; tubercle III, .07 to .12 mm.; IV, inconspicuous.\*

Antennal III with 11 to 21 sensoria; of 48 antennae 1 had 11, 2 had 13, 1 had 14, 4 had 15, 9 had 16, 10 had 17, 10 had 18, 9 had 19, 1 had 20 and 1 had 21 sensoria. Antennal VI with 4 accessory sensoria around the primary sensorium. Abdominal tubercles I and II usually represented only by a dark spot, IV distinct but short and broadly joined at the base (Fig. 4)

*Type locality:* Brigham Canyon, Utah.

*Types:* Holotype in the United States National Museum; paratypes and paratypes in the collections of the writers, of the Utah Agricultural Experiment Station and in various other aphid collections.

*Collections:* On *Acer grandidentatum* in Utah at Brigham Canyon, July 1, 1937, the holotype slide (5 specimens) and 3 paratype slides (15 specimens), June 3, 1937, 1 paratype slide (1 specimen), September 15, 1928, 1 paratype slide (1 specimen), October 5, 1929, 1 paratype slide (1 specimen); Blacksmith Fork Canyon, September 25, 1926, 1 paratype, May 18, 1928, 1 paratype; City Creek Canyon, September 4, 1934, 2 paratype slides (10 specimens), September 22, 1942, 2 paratype slides (7 specimens); Honeyville, September 12, 1925, 1 paratype slide (2 specimens); Huntsville, July 21, 1942, 1 paratype slide (4 specimens); Liberty, July 21, 1942, 1 paratype slide (5 specimens); Logan Canyon, September 21, 1928, 1 paratype slide (4 specimens), May 25, 1929, 1 paratype slide (8 specimens), June 16, 1938, 1 paratype slide (2 specimens), May 11, 1940, 1 paratype slide (6 specimens); Mt. Sterling, 2 paratype slides (4 specimens); Mueller's Park (Davis County), June 16, 1942, 1 paratype slide (6 specimens); North Ogden, July 21, 1942, 1 paratype slide (4 specimens); Ogden Canyon, May 20, 1930, 3 paratype slides (5 specimens), June 4, 1937, 1 paratype slide (4 specimens); Peterson, September 14, 1925, 1 paratype slide (1 specimen); Pinecrest, June 21, 1925, 1 paratype slide (1 specimen); Providence Canyon, June 5, 1933, 1 paratype slide (3 specimens); Smithfield Canyon, July 11, 1937, 1 paratype slide (4 specimens).

The writers also have more than 100 other slides which appear to be this species. This material is not placed in the paratype series because most of the specimens have a lighter colored head, thorax, cornicles and tubercles than on the typical *utahensis* material. It is possible that these belong to another species but thus far the writers have been unable to discern consistent differences other than color in the material studied; and it may be the light colored specimens are teneral as the color differences are intergrading. These paler specimens were collected in Utah at American Fork Canyon, Beaver Canyon, Big Cottonwood Canyon, Brigham Canyon, Eden, Emigration Canyon, Lakota, Mantua, Millville, Mt. Nebo, Oak Creek Canyon, Parley's Canyon, Providence Canyon, Provo Canyon, Richmond, Sardine Canyon and Uinta. This pale form has been collected in Idaho at Boise (Minidoka National Forest), Franklin, and Mink Creek. The Oak Creek material all had an unusually heavy white covering of wax over the body.

#### ADDENDA

After comparison with paratypic specimens of *Aphis fraternus* Strom,<sup>3</sup> the writers consider *Brevicoryne salixutis* S. & K. to be a synonym. The species *fraternus* is difficult to classify generically. At first glance one might place it in the genus *Aphis*, another worker might consider it a *Brevicoryne*. In most keys it might fall either in *Brevicoryne* or in *Rhopalosiphum*. After further study of the general characteristics of the species, the writers now consider that it would be best to place it in the genus *Rhopalosiphum*, and be known as *Rhopalosiphum fraternus* (Strom).

<sup>3</sup> The writers wish to express their appreciation to Mr. L. G. Strom for the loan of specimens of *Aphis fraternus* and for his opinions concerning its synonymy.

## EXPLANATION OF PLATE 22

Unless stated otherwise, the figures refer to the lateral view of the dorsal abdominal tubercles.

*Drepanaphis granovskyi* n. sp. 1, tubercles; 2, antennals II and III; 3, cornicle

*D. utahensis* n. sp. 4, tubercles; 5, cornicle; 6, antennals II and III.

*D. sabrinae* Miller. 7, tubercles; 12, section of antennal VI showing characteristics of sensoria (much enlarged).

*D. acerifoliae* Thomas. 8, tubercles.

*D. carolinensis* Smith. 9, tubercles; 10, section of antennal VI showing characteristic arrangement of sensoria (much enlarged).

*D. kansensis* Smith. 11, tubercles, with a caudal view of tubercle III.

*D. parvus* Smith. 13, tubercles.

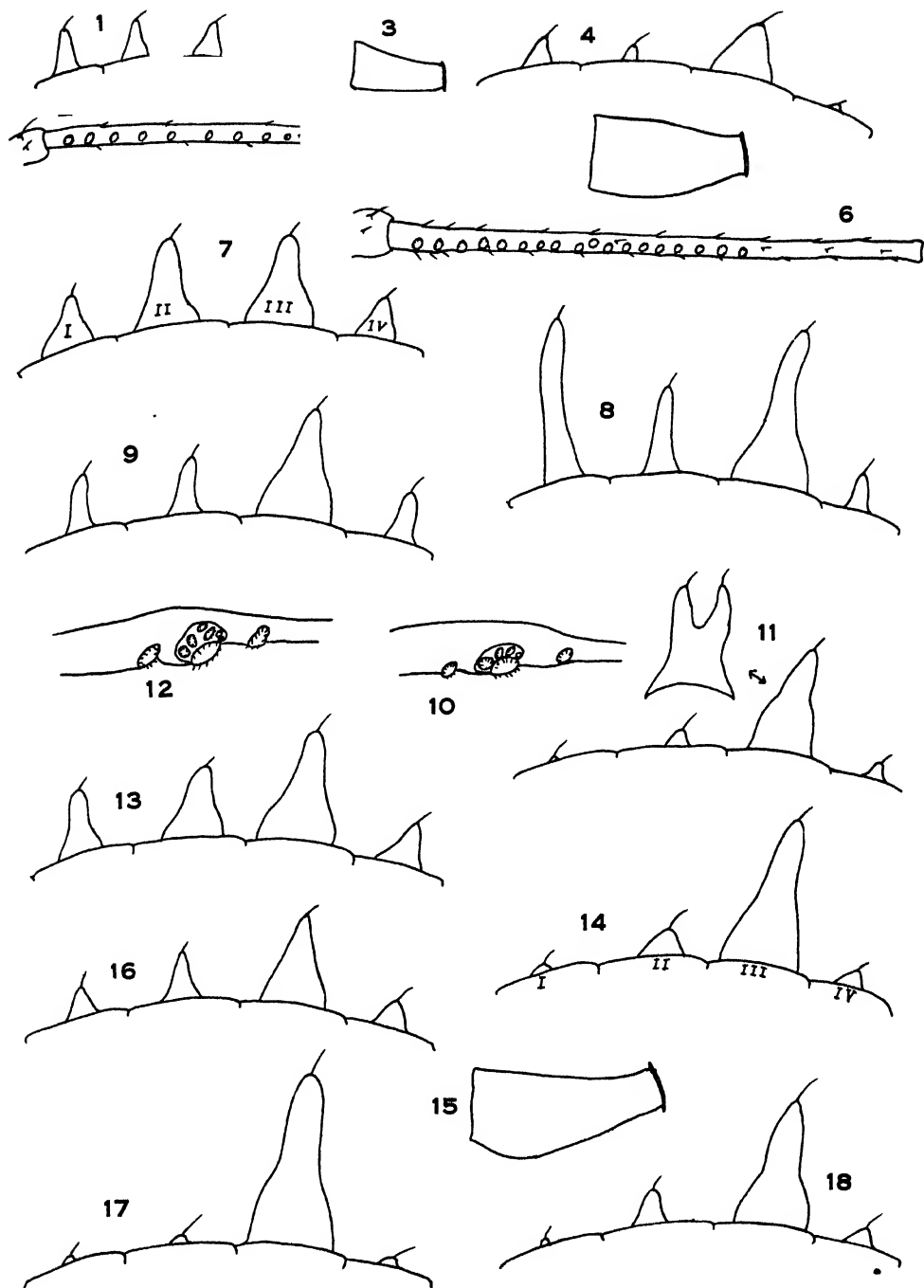
*D. monelli* Davis. 14, tubercles

*D. spicatum* Smith. 15, cornicle; 18, tubercles.

*D. nigricans* Smith. 16, tubercles.

*D. keshenae* Granovsky. 17, tubercles.

# PLATE 22





# THE DISSOCIATION CONSTANTS AND OPTICAL ACTIVITY OF QUITENINE

BY JAMES C. ANDREWS AND W. E. CORNATZER

Among the numerous derivatives of quinine, quitenine has received some attention as being a possible product of the metabolic destruction of this drug (1). Quitenine is readily formed from quinine by oxidation of the latter with permanganate (2) by which treatment the vinyl group of quinine is oxidized to carboxyl with elimination of one mole of carbon dioxide.

Indirect evidence that the metabolic destruction of quinine is, at least in part, an oxidative procedure lends plausibility to consideration of quitenine as one possible oxidation product. Examination of urines collected after quinine administration, for the presence of quitenine requires, as a preliminary, more exact knowledge than is now on record concerning the properties of this substance. The present paper reports physicochemical data on dissociation constants, optical activity, and solubility in the isoelectric condition.

Whereas quinine is a base with two dissociation constants corresponding to its two basic nitrogen atoms, quitenine has in addition a carboxyl group. As an antimalarial it is practically inert (3, 4) but it is of considerable interest that several of its alkyl esters, particularly butyl and amyl, do show antimalarial activity comparable with those of the principal cinchonas. It is suggestive that quinine, the base, when converted to an ampholyte is inert but that on destruction of its amphoteric properties by esterification, antimalarial properties are at least partially resumed. As pointed out by Buttle *et al.* (4), variations in digestive hydrolysis of these esters may well produce the irregularities which have been observed in the results of antimalarial testing. Questions such as the above and others indicate the need for more exact information as to the physicochemical properties of this derivative. The determination of its dissociation constants is described below.

*Dissociation Constants.* A sample of quitenine, supplied to the authors through the kindness of Merck and Company, showed, after drying to constant weight, 67.14% carbon and 6.84% hydrogen (theory: 66.65% carbon and 6.48% hydrogen). The sample melted with decomposition at 291°C. with rapid heating whereas the literature value under these conditions is 290°C. Its optical activity was  $-297.3$  as compared with the literature value of  $-298$ , both determined in 5% solution in normal sulfuric acid. As will be noted below, this value varies only slightly from that obtained by the authors on the same sample after recrystallization four times.

Although isoelectric quitenine is very insoluble in water at room temperature, the solubility mounts rapidly with increased temperature. The above material was therefore recrystallized four times from boiling water and the resulting sample dried to constant weight at 110°C. This sample was used for all determinations described below.



The titration curve of quitenine was determined by titrating weighed samples with equivalent amounts of standard acid and alkali to the point of formation of the dihydrochloride and the sodium salt respectively, then titrating back progressively, and reading the resulting pH by means of the glass electrode in a Beckman, Model G, pH meter reading to  $\pm 0.01$  pH. All titrations were conducted at 25°C. The resulting data are shown in Table I. The results of this table are expressed on the assumption that the two basic constants are on the acid side of the isoelectric point and the acid constant on the basic side, i.e., no "Zwitterion" formation is assumed.

TABLE I  
*Titration Curves of Quitenine*

LOG $\frac{\text{SALT}}{\text{AMPHOLYTE}}$	pH	pK <sub>b1</sub>	LOG $\frac{\text{SALT}}{\text{AMPHOLYTE}}$	pH	pK <sub>b1</sub>	LOG $\frac{\text{SALT}}{\text{AMPHOLYTE}}$	pH	pK <sub>a</sub>
0.34	2.90	10.68	-0.04	4.00	9.96	-0.56	9.11	9.67
0.26	2.99	10.67	-0.07	4.11	9.88	-0.53	9.22	9.75
0.24	3.00	10.68	-0.23	4.15	10.00	-0.35	9.25	9.60
0.09	3.09	10.74	-0.42	4.19	10.15	-0.31	9.45	9.76
0.06	3.10	10.76	-0.53	4.40	10.05	-0.24	9.37	9.61
-0.03	3.12	10.83	-0.66	4.42	10.16	-0.13	9.49	9.62
-0.06	3.18	10.80	-0.67	4.53	10.06	+0.04	9.52	9.48
-0.17	3.22	10.87	-0.79	4.65	10.06	+0.05	9.55	9.50
-0.20	3.25	10.87						
Average .....		10.77			10.02			9.62

The following simple working formulas were used. For the acid side of the isoelectric point:

$$\text{pK}_b = 13.92 - \text{pH} - \log \frac{\text{salt}}{\text{ampholyte}}$$

For the alkaline side of the isoelectric point:

$$\text{pK}_a = \text{pH} - \log \frac{\text{salt}}{\text{ampholyte}}$$

No other corrections were applied.

Expressed in terms of their position on the pH scale it will be seen that these three constants correspond to the following:  $\text{pK}_1 = 3.15$ ,  $\text{pK}_2 = 3.90$  and  $\text{pK}_3 = 9.62$ . The drift in values observed in Table I appears to be attributable to two causes. The two values assigned to the two basic constants (at pH 3.15 and 3.90) are so close together that each curve is distorted by the other. To minimize this distortion we have avoided using data from that region where the two curves join (from pH 3.25 to 4.00). In addition, the insolubility of the isoelectric material (isoelectric point = pH 6.75) in water at room temperature necessitated the use of more dilute solutions than would be otherwise desirable. For these reasons the first two values recorded above should be considered as only approximate.

**Optical Activity.** As described above, isoelectric quitenine, recrystallized four times from boiling water was used for these measurements. This quinine derivative shows very little solubility in organic solvents. Dry ether at 25°C. dissolves about 2 mgm. per 100 ml. of solvent; chloroform dissolves still less. It is obvious that if present in urine following quinine administration it could not be extracted with such immiscible solvents. Indeed, unless its water solubility were much increased by the presence of other urinary constituents it could hardly be appreciably present in solution except in very acid urines. Solubility determinations at 25°C. in pure water showed an average of 31.9 mgm. per 100 ml. of the solution. This saturated water solution of the isoelectric material gave, in a 2 dm. tube at 25°C., an observed rotation of  $-0.12^\circ$ . This amounts to a specific rotation of  $-188.0^\circ$ . In absolute ethyl alcohol the solubility was 14.4 mg. per 100 ml. solution. This, under the above described conditions gave an observed  $\alpha$  of  $-0.08$  or  $[\alpha]_D^{25} = -277.5$ .

TABLE II  
*Optical Activity of Some Salts of Quitenine in Aqueous Solution*  
(All figures are expressed in terms of the free ampholyte)

SALT	C. gm per 100 ml.	$[\alpha]_D^{25}$
B·HCl.....	0.100	-303.0
B·2HCl ...	1.000	-307.0
B·2HCl ...	0.200	-305.0
B·4HCl ...	0.200	-305.0
B <sub>2</sub> ·H <sub>2</sub> SO <sub>4</sub> ...	0.200	-300.0
B·H <sub>2</sub> SO <sub>4</sub> ...	0.200	-305.0
B·2H <sub>2</sub> SO <sub>4</sub> .....	0.200	-305.0
B·NaOH.....	0.200	-122.6
B·2NaOH.....	0.200	-122.6
B·4NaOH .....	0.200	-122.0

The optical activities of some salts of quitenine are shown in Table II. For each salt several stoichiometric ratios of the ampholyte to the acid or base are given. In some cases these ratios represent salts that have been isolated and described. In other cases they represent the molar ratio of ampholyte to acid or base used without regard to demonstrated existence of such a salt. For example, the mono- and dihydro-chlorides (B·HCl and B·2HCl) have already been described but not any such salt corresponding to B·4HCl. The fact that increased amounts of acid sometimes have a marked effect on the optical activity prompted us to examine the solution in this proportion but it is obvious from the table that no detectable change was found in the specific rotation. The same may be said of the other salts. Moreover, the two values for the dihydrochloride differing only in a five-fold difference in concentration show that, contrary to the cases of some other ampholytes, concentration is not an important factor. It should be remembered that all values are expressed as the free isoelectric ampholyte, regardless of the salt used.

## CONCLUSIONS

The dissociation constants of quitenine in aqueous solution at 25°C. have been determined as having the following values:  $pK_a = 9.62$ ,  $pK_{b_1} = 10.02$ ,  $pK_{b_2} = 10.77$ . The close proximity of the two basic constants causes each curve to distort the other and renders these values less accurate.

Some data for the isoelectric solubility of quitenine in water, absolute ethyl alcohol and ether are presented.

The optical activities of several salts of quitenine have been determined. These include varying ratios of the ampholyte to acid or base for the hydrochloride, the sulfate and the sodium salt. The hydrochlorides and sulfates show practically identical values, regardless of varying ratios of ampholyte to acid, and these values are not markedly affected by dilution.

## ACKNOWLEDGEMENT

The writers wish to acknowledge the assistance of the Samuel S. Fels Fund in providing the means for carrying on this work. They also wish to acknowledge the courtesy of Dr. D. A. MacPherson, of the Department of Bacteriology of this Medical School, for placing at their disposal the Beckman Glass Electrode pH meter.

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# MESOCYCLOPS EDAX (S. A. FORBES), M. LEUCKARTI (CLAUS) AND RELATED SPECIES IN AMERICA\*

By R. E. COKER

TEXT FIGURES 1-43

## *The Genus Mesocyclops*

What is probably our most common limnetic cyclopoid has been called (variously) *Cyclops edax* S. A. Forbes, *C. leuckarti* Claus, or *C. leuckarti edax* Forbes, although in recent years only the name *leuckarti* has been in common use in America. The copepod is one of a small group which G. O. Sars in 1918 set apart in a new genus *Mesocyclops*, with 5 species in Norway. Schmeil (1892) had previously recognized the "*leuckarti-oithonoides* Gruppe", with *leuckarti* Claus, *oithonoides* Sars (and its variety *hyalina* Rehberg) and *dybowski* Lande. To the group set up by Schmeil, Sars merely added *C. crassus* Fischer and *C. gracilis* Lilljeborg and applied a generic name.

Kiefer (1927, 1929) adopted Sars' name for the genus typified by *leuckarti* Claus, and restored the name *leuckarti*, instead of *obsoletus* Koch, employed by Sars. He removed one of the species included by Sars (*C. gracilis* Lilljeborg) to another genus, reorganized and redescribed other species and subdivided the small genus into 2 subgenera: *Mesocyclops* s. str. and *Thermocyclops* Kiefer. He also added Forbes' *edax* among the subspecies of *leuckarti* and *C. tenuis* Marsh, both of North America, 4 South American species (*C. longisetus* Thiébaud, *C. annulatus* Wierzejski, *C. meridianus* Kiefer and *C. brehmi* Kiefer), Smirnov's *rylovi* from the Caucasus and 6 species from Africa.

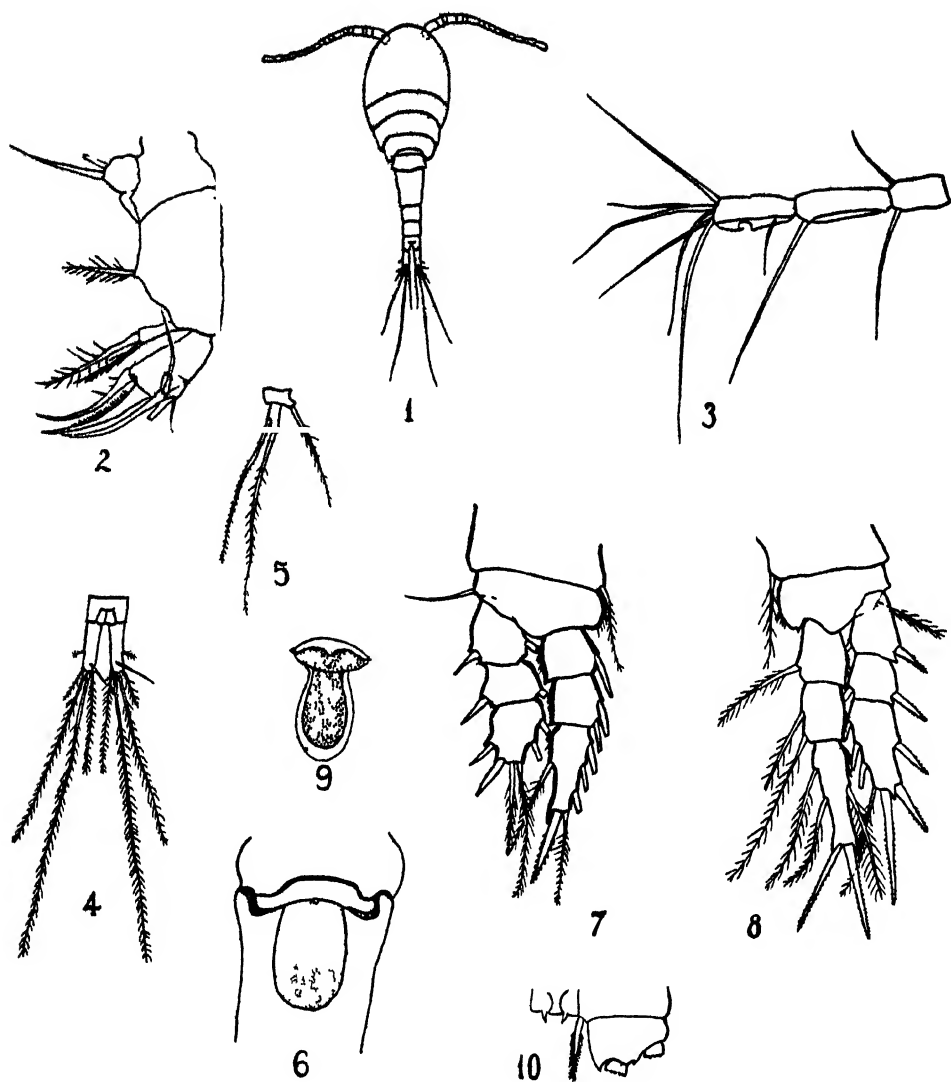
Subsequently, Kiefer treated *Thermocyclops* as a distinct genus. The difference between the two genera is merely that in *Mesocyclops*, typified by *leuckarti*, the spine on the second segment of the fifth foot is on the mesial border while in *Thermocyclops*, typified by *oithonoides*, it is terminal or nearly so.

Gurney (1933) went back to the plan of Schmeil and Sars, including in a subgenus *Mesocyclops*, *C. leuckarti* Claus, *C. hyalinus* Rehberg and *C. dybowski* Lande for the British Isles. He had studied *longisetus* Thiébaud and regarded it as distinct, but he had no occasion to place the other non-British species.

Many species assignable to the group have since been described by Kiefer and others, including, for America, *M. brazilianus* Kiefer (1933), *M. minutus* Lowndes (1934), *T. inversus* Kiefer (1936), and *M. ellipticus* Kiefer (1936). *Cyclops crassus* Fischer seems now to be unrecognizable or in the synonymy of *hyalinus*; and *C. gracilis* Lilljeborg has been transferred by Kiefer and Gurney to another group.

This genus, or the subgenus, if one prefers, may now be said to include, besides the type species, *M. leuckarti* Claus, one or two other species of nearly worldwide

\* Mr. Harry C. Yeatman, formerly graduate student but now in military service, has given substantial aid in this study.



Figures 1-10. *Mesocyclops leuckarti* from Hewett's Millpond, from original drawings by Yeatman

Figure 1. The whole, showing general form.

Figure 2. 2nd maxilla.

Figure 3. Terminal segments of antenna.

Figure 4. Last abdominal segment and furcal rami.

Figure 5. Fifth foot.

Figure 6. Seminal receptacle.

Figure 7. First foot.

Figure 8. Fourth foot.

Figure 9. Seminal receptacle of *M. leuckarti*, after Sars.

Figure 10. Connecting plate of fourth feet of *M. leuckarti*, after Gurney.

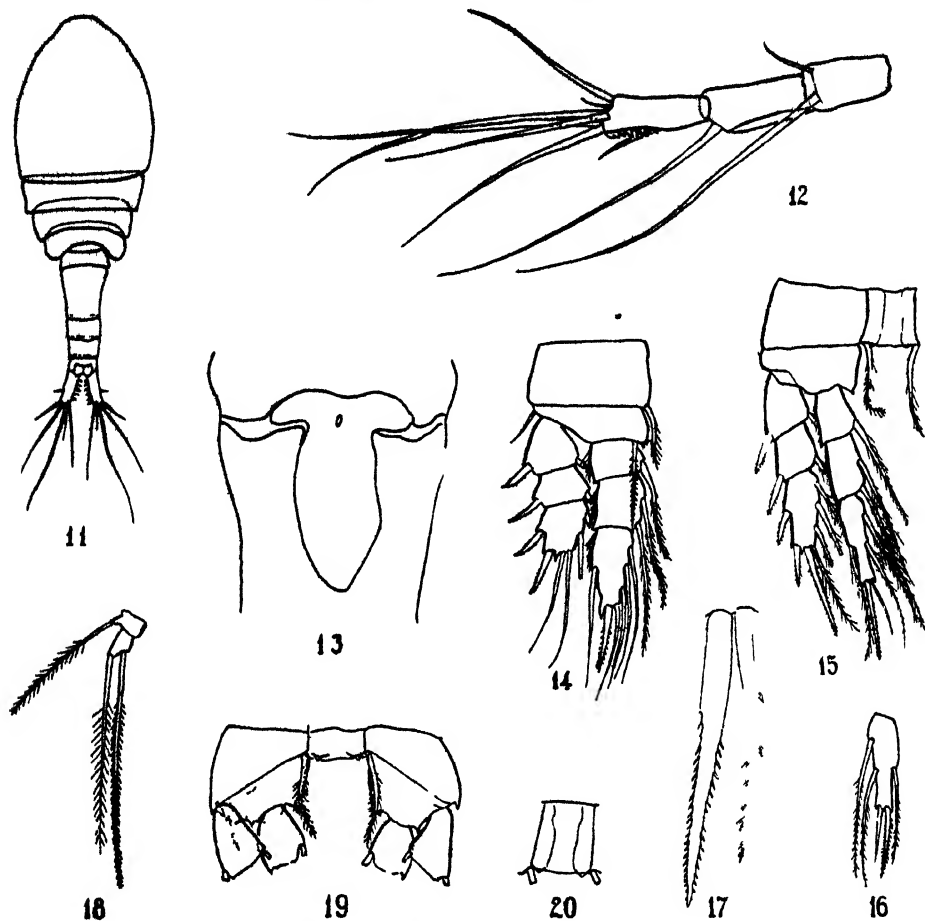
distribution (if reports of them from America and Africa are sustained—*M. oithonoides* Sars and *M. hyalinus* Rehberg), one species of the northern part of the eastern hemisphere (*M. dybowski* Lande), 2 known recently only from America (*M. edax* S. A. Forbes, *M. tenuis* Marsh), 8 recorded previously only from South America (to be listed later), and many others recently described from Africa and other regions of recent exploration as to copepods. Lowndes (1934) and Kiefer (1936) have recorded *M. (T.) tenuis* Marsh from Paraguay and Brazil, respectively, and we now record *inversus* Kiefer from Central America.

Gurney, in discussion of *hyalinus*, said in 1893: "I have had for comparison specimens from Ceylon, India, Egypt and the Sudan. None of these agree completely with the European form, neither do those from India and Ceylon agree exactly with those from Egypt and the Sudan. None the less I feel no doubt that all represent one species, of wide range and local and individual variability. \*\*\* No less than 27 species of 'Thermocyclops' have now been described, several of which differ less from typical *C. hyalinus* than some of these Indian and African specimens do, and it seems there need be no end to the number that may be described in future if reliance is placed on minute differences in lengths of segments, spines and setae. It is desirable that the range of variation of the European form should first be established, and that these new species should be revised in the light of the results" (p. 300, 301).

Gurney's comments are even more worthy of consideration now, since, in the past decade, the number of species have grown apace. Some sort of significance would seem to attach to the fact that, in such large areas as most of North America and Europe and the British Isles, where the copepods are better known, the copepods of this group fall readily into 3 or 4 species, whereas there appear to be an almost indefinite number of species in regions that have been little studied and from which only small collections have been available. It is quite possible that, although some of these are genetically distinct, others will prove to be merely phenotypic variants. Breeding tests are much needed for the copepods of South America, Africa and the southern hemisphere in general, where specific diversity in this group seems most prevalent. We know for another group of copepods, represented by *C. vernalis* Fischer, that often the most conspicuous phenotypic differences occur or may be caused to occur with copepods of the same parentage, but also that some very inconspicuous differences are coupled with something invisible which seems to produce genetic isolation. It is known from the experiments of Lowndes, that *leuckarti* is very variable, particularly in the form of the hyaline plate on the antenna, which has sometimes played a prominent part as a diagnostic character.

Obviously, if many of the species described in the last couple of decades and based upon relative lengths of spines and processes prove to be valid it will not be a simple matter to identify with assurance the copepods of this group. We do not attempt in the following pages to consider the whole group. It is intended here only to discuss the history and status of knowledge of North

American species and to offer a key and diagnoses for the determination of those recorded from North, Central, and South America.



Figures 11-20: *Cyclops edax*; figs. 11-15 from original drawings by Yeatman of copepods from Bléwett's Falls, N. C.

Figure 11. Whole.

Figure 12. Terminal segments of first antenna.

Figure 13. Seminal receptacle.

Figure 14. First foot.

Figure 15. Fourth foot.

Figure 16. Fourth foot. End segment of endopod.

Figure 17. Fourth foot. Terminal "spines" of endopod, drawn with oil immersion lens.

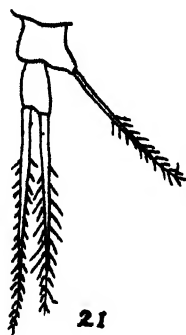
Figure 18. Fifth foot.

Figure 19. Basal portion of fourth pair of feet showing connecting plate.

Figure 20. Connecting plate of fourth feet.

It is noteworthy that, in contrast to the copepods of some other groups, there seems to be less diversity in respect to the number of segments of the antennae, which is always 17. In some descriptions a point is made of the presence or ab-

sence of a hyaline plate on the last two segments of the antenna, of the form of this plate, or of the relative length of these segments; but the number of segments shows surprising constancy. At least so far as the record goes, the "spine formula" is practically invariable. In only one species do the proportions of the furca deviate far enough from the mean to have evident significance, but the relative lengths of the setae on the furca and the presence or absence of hairs on



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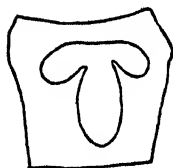


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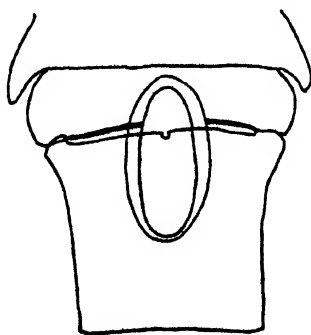
Figures 21 and 22: *M. annulatus*, after Wierzejski

Figure 21. Fifth foot.

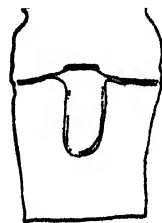
Figure 22. Connecting plate of fourth feet.



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Figure 23. Seminal receptacle of *M. longisetus*.

Figure 24. Seminal receptacle of *M. ellipticus*.

Figure 25. Seminal receptacle of *M. meridianus*.

the inner margins of the rami have been taken as distinctive specific characters. The picture is so different with the group of *C. vernalis*, where the number of segments in the antenna characteristic of particular species varies from 10 to 17, and the spine formula (expressing the number of spines of the terminal segments on the exopod of the four swimming feet) is extremely variable, even with copepods of the same immediate parentage, and where proportions of furcal rami show characteristic and fairly extreme patterns.



In the group of *C. leuckarti* we find generally playing the most prominent part in specific diagnoses the relative lengths of the spines on the end of the endopod of the fourth foot, the presence or absence of smooth or spinous prominences on the connecting plate of the fourth feet, the relative lengths of the lesser-developed furcal setae, and especially the length of the dorsal seta, the position of the lateral spine on the furca, and the presence or absence of hairs on the inner margins of furcal rami. Breeding and experimental studies are needed to determine the actual dependability of these characters as specific distinctions.

It is of some general interest that in one group of copepods a particular assortment of structural features (spine formula, segmentation of the antenna, etc.) should be the basis of individual, varietal and specific diversity of form, and in another group the corresponding characters should be so fixed among individuals and species that even small deviations from type never catch the observer's attention, while in the second group other characters come so much to the fore as the basis of individual and specific distinction. After making due allowance for the subjective qualities of the taxonomists who plan the system of classification, there would seem to be ground for assuming that in different sections of the copepod world the most effective mutation rates prevail in different parts of the structural complex.

*M. leuckarti* Claus vs. *M. edax* S. A. Forbes

*Cyclops leuckarti* was originally described by Claus in 1857, the essential parts of his description being, in translation, as follows:

"A small dainty species with a slender body and elongated abdomen. The first antennae scarcely reach the length of the 3 anterior thoracic segments and are distinguished by the very uniform breadth of the several segments. After the width has been gradually reduced in the first few segments, it is maintained fairly uniformly through the following segments. A particular recognition character of the moderately developed mouthparts is the series of small indentations found on the dorsal side of the base of the 2nd broad maxillary foot (2nd maxilla), giving the appearance of a beaded contour. Characteristic also is the long furca which terminates the very extended abdomen. The outer border seta is attached rather far from the end, while the inner [dorsal?], and the longer, is placed much nearer the apex. The outermost of the four weakly barbed terminal setae is almost as long as the furca; the next one equals the last three segments and furca combined. The third greatly exceeds the second in length, and, finally, the inner is about twice as long as the outer." (See our fig. 1.)

For a more complete description of the species one may refer, as for most common cyclopoid copepods, to Schmeil's classical monograph (1892). Just before Schmeil published, S. A. Forbes (1891) described under the designation *C. edax*, a new species, which is certainly closely related to *C. leuckarti*, but his figure distinctly shows hairs on the inner margins of the furca, although this difference is not mentioned in the text. The antennae are described also as without serrations, acute spines, or other special armature, except a stout spine at the tip of the 6th segment. The spine, at least, would seem to be an abnor-

mality. He notes "the absence of a knife-like ridge" (hyaline membrane) on the last 2 segments of the antenna, but he was later corrected as to this point by E. B. Forbes.

Unfortunately *C. edax* could not be considered by Schmeil in connection with his account of *leuckarti*. He mentioned Herrick's identification of *C. simplex* Poggenpol, which he reduced to the synonymy of *C. leuckarti* Claus. Schmeil also referred to Herrick's *C. tenuissimus* as being not definitely recognizable. Kiefer has placed this doubtfully in the synonymy of *oithonoides*.

A few years later, E. B. Forbes (1897) gave revised descriptions of both *leuckarti* Claus and *edax* Forbes, having available, it appears, the type material of *edax*.

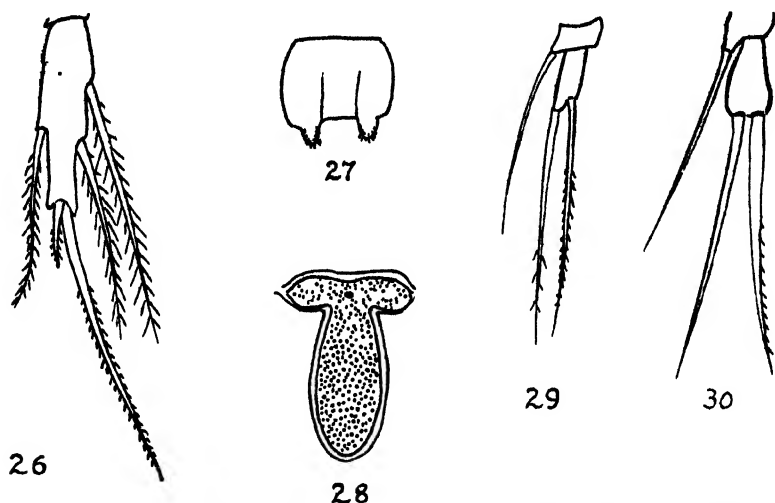


Figure 26. End segment of endopod of fourth foot of *M. oithonoides*, after Sars.

Figure 27. Connecting plate of *M. oithonoides*, after Sars and Kiefer.

Figure 28. Seminal receptacle of *M. oithonoides*, after Sars.

Figure 29. Fifth foot of *M. oithonoides*, after Sars.

Figure 30. Fifth foot of *M. hyalinus*, after Kiefer.

He distinguished the two species chiefly by the following characters: (1) The hyaline plate on the terminal segment of the antenna in *edax* is cut by a series of deep oblique notches forming teeth which point strongly backward, the notches being deepest near the distal end and thence diminishing in both directions; the plate merely completes the outline of a deeply excavated segment; in *leuckarti* the segment is but slightly excavated and the broad plate extends beyond the segment; his figure shows only one deep notch for that species, but his description does not mention the notches. (2) The last two segments of the antenna are about equal in *edax*, while in *leuckarti* the 16th is a fourth larger than the last. (3) The two pointed teeth of the connecting lamella of the fourth feet of *edax* are less sharp and are placed farther apart than in *leuckarti*. (4) The transverse ridges of the outer maxillipeds characteristic of *leuckarti* are absent or incon-

spicuous in *edax*. (5) The furca rami are more divergent in *edax*. (6) The fifth feet are markedly differently, chiefly in that the distal segment is much broader relative to length in *edax*. (See our figs. 5 and 18.)

Forbes regarded *leuckarti* as rare in America, although he had found immense numbers in one collection from the Fox River, Illinois. According to him, it is widely distributed in lakes and rivers, but not reported from temporary pools. *Edax*, on the other hand, "is very abundant and widely distributed in America."

Forbes did not mention the presence of inner marginal hairs on the furca of *edax* and its absence in *leuckarti*. Nevertheless, his figure of *edax* showed very short hairs in that place, although he did not show them in definite clumps as we find them. Schmeil did not mention or figure such hairs for *leuckarti*, which is a good indication of their absence. Forbes thought that Wierzejski's *C. annulatus* (1892) was synonymous with *edax*, and this may prove to be the case.

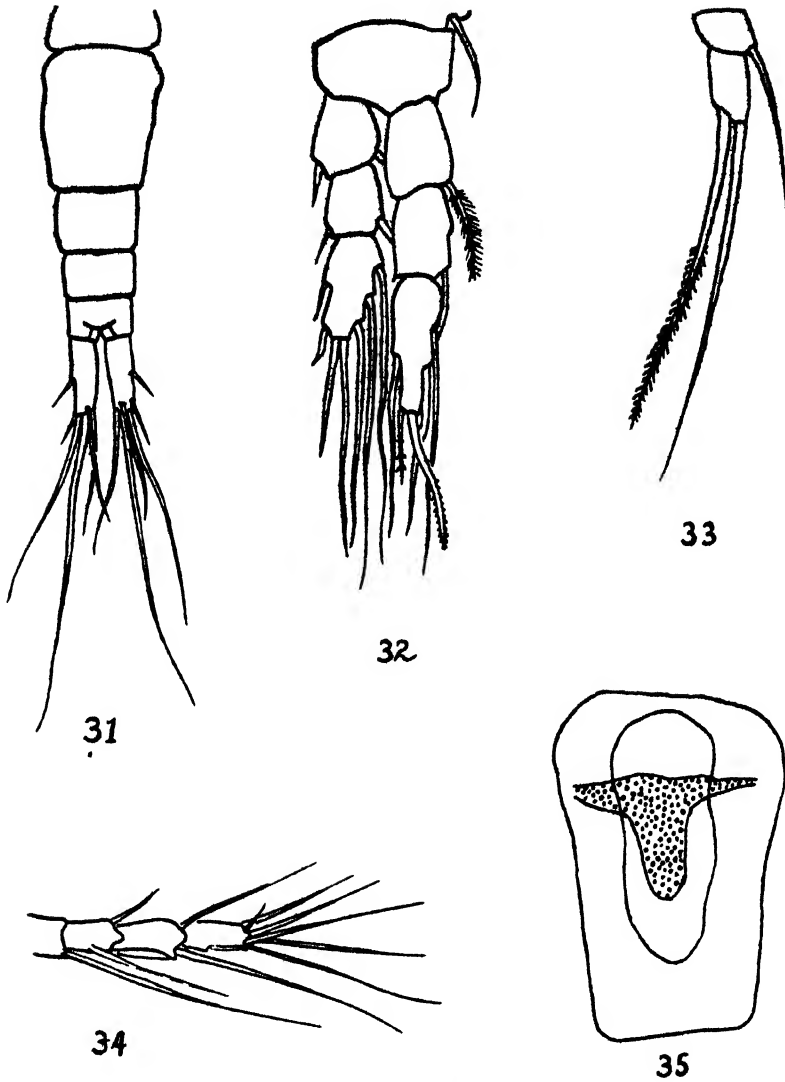
Marsh (1910) discussed the difference between *edax* and *leuckarti* that E. B. Forbes had adduced, but concluded that none of them were of more than varietal value. He had found both forms of the hyaline membrane of the 17th segment of the antenna in the same collection, the single indentation being more abundant, and he concluded that there was "every reason to think that the two forms grade into one another." Although E. B. Forbes had found many points of distinction between *edax* and Hoek's *leeuwenhoekii*, Marsh concluded that, if the form designated as *edax* were to be recognized as a distinct species, it should bear the name *leeuwenhoekii* Hoek, as of prior standing. The last mentioned species is now in the synonymy of *C. leuckarti*.

Marsh also placed Byrnes' *C. pulchellus* (1909) in the synonymy of *leuckarti*.

Sars (1918) went back to Koch's name of *C. obsoletus*; reducing *leuckarti* Claus, *simplex* Poggenpol, and *acourfieldi* Brady to synonymy. He did not mention hairs on the inner margins of the furca, which his figures depict as bare. He mentioned and figured just one conspicuous semilunar notch on the hyaline plate of the terminal segment of the antenna. His figures exemplify all of Forbes' six distinguishing features of *leuckarti*, listed above, except the second. He mentioned the North American species, *C. edax* Forbes, as another member of the genus *Mesocyclops*, and assigns both *obsoletus* (*leuckarti*) and *oithonoides* to North America, the latter on the authority of Herrick, which is doubtful.

Pesta's (1928) description of *C. leuckarti* made no mention of hairs on inner margins of furca. He described the hyaline membrane of the end segment of the first antenna as having a deep sickle-shaped notch.

Kiefer (1929) described *C. leuckarti* as having the furcal rami 3-3½ times as long as broad, little divergent, with the mesial borders generally bare; the two end-segments of the antenna with hyaline membrane, that of the terminal segment having in its distal half a great rounded notch, rarely with two or three smaller notches proximal to which the margin is often finely toothed. These characterisations obviously allow for a good deal of diversity, but presumably they were given so broadly in order to cover *edax*, which he included as a subspecies. Kiefer then listed a number of distinctive features for *M. leuckarti edax* E. B. Forbes: copepods of this subspecies have hairs on the inner margins of the



Figures 31-35: *M. tenuis*, Marsh

Figures 31-33 from original drawings by Yeatman, made from Panama copepods

Figure 31. Last thoracic segment, abdomen and furca of *M. tenuis*.

Figure 32. Fourth foot.

Figure 33. Fifth foot.

Figure 34. Terminal segments of antenna of *M. tenuis* from Paraguay, after Lowndes.

Figure 35. Seminal receptacle of *M. tenuis*, after Marsh.

furcal rami; the hyaline membrane of the end joint of the first antenna of the female has several deep notches and so appears to be grossly toothed; the two terminal spines on the end-joint of P4 endopod are very different in length, the inner being only about two-thirds the length of the outer; the spine on the inner

side of the end-joint of P5 is longer than the end setae, instead of being shorter as in the typical *C. leuckarti*. The subspecies was ascribed only to North America.

Kiefer (1931) in material sent him by Professor Hutchinson found both *M. leuckarti* and "*M. leuckarti edax*," the former from Cape May County Farm in New Jersey and the latter from a deep pond near Falmouth, Mass.

Gurney, 1933, described *C. leuckarti* as having the inner margins of the furca smooth "except in forma *pilosa* Kiefer, from Madagascar and S. Africa." With respect to the hyaline membranes on the last segments of the antennae, he said: "membrane of seg. 16 generally very finely serrated; that of seg. 17 more coarsely

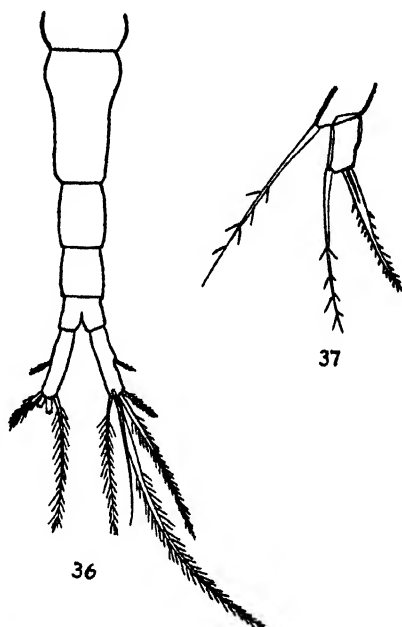
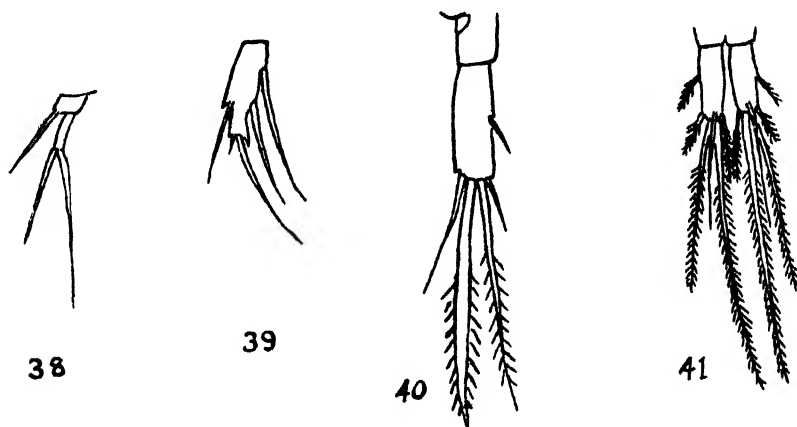


Figure 36. Last abdominal segment, abdomen and furca of *M. brehmi*, after Kiefer.  
Figure 37. Fifth foot of *M. brehmi*, after Kiefer.

serrated, and with one or more conspicuous notches anteriorly." His figures show variation in the hyaline membrane of the seventeenth segment, but only those of examples from Lake Tiberias, Ceylon, Victoria Nyanza, and Borneo are shown with a single deep notch, and in all cases there are very evident and sometimes most conspicuous serrations of the entire margin. Without expressing a personal opinion he quoted Marsh as recording from North America both the typical form and a subspecies, *C. l. edax*, characterized by having the inner margins of the rami hairy. He mentioned two closely allied South American species, *C. longisetus* Thiébaud and *C. annulatus* Wierzejski, the former differing from *C. leuckarti* in having an inner seta on the basis of leg one. Finally, he regarded *C. leuckarti* as cosmopolitan with the possible exception of South America.

Gurney describes the apical spines of P4 end. as with the outer generally a little longer but occasionally shorter than the inner. On the distal segment of P5, the long inner spine is nearly as long as the apical seta.

In collections from various parts of the country, including New York, Oklahoma, North Carolina and Mexico (see p. 193 below) we have, with one exception, found only *edax*. The exception is a haul of plankton made by Yeatman and the writer in Hewitt's Millpond, near Beaufort, N. C. The copepods from that pond seemed to be perfect examples of the type species *leuckarti* and enable us to make a direct comparison between *leuckarti* and *edax*. It seems very clear that we have to do with distinct species, *edax* being, as E. B. Forbes recognized long ago, the more common and widely distributed. Even with later knowledge of the general variability of the species, E. B. Forbes' six points of distinction



Figures 38-41. *M. minutus* Lowndes

Figure 38 Fifth foot, after Lowndes.

Figure 39 Terminal segment of endopod of fourth foot, after Lowndes.

Figure 40. Furcal ramus, after Lowndes.

Figure 41. Furcal ramus, after Kiefer.

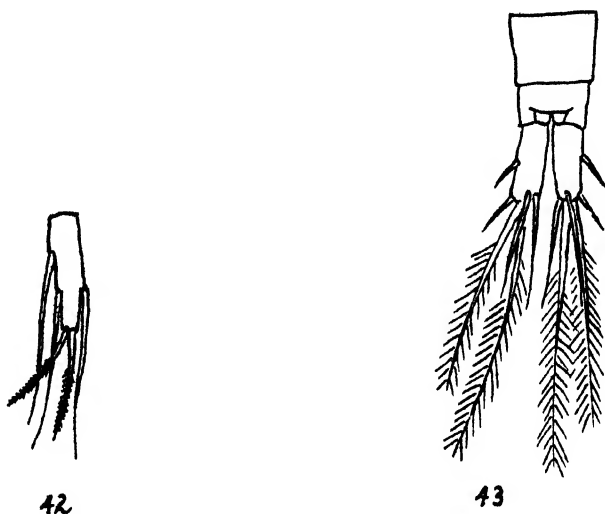
are generally valid; and more positive features of distinction are the presence in *edax* of clumps of hairs on inner margins of the furca and a seta at each inner angle of the basipod of the first feet, lacking in *leuckarti*, as Gurney has said.

The principal distinctive features of *edax* as compared with *leuckarti* are: the hairs on inner margins of divergent furcal rami (cf. figs. 4 and 11); the greater length of the inner spine of the second segment of the fifth foot as compared with the terminal seta (cf. figs. 5 and 18); the presence of a seta on the mesial angle of the basipod of the first foot (cf. figs. 7 and 14); the greater difference between the terminal spines of the endopod of the fourth foot (cf. figs. 8 and 16); and the protuberances on the connecting plate of the fourth foot, high, acute and close together in *leuckarti*, low, rounded and more widely separated in *edax* (cf. figs. 10 and 20); the notches in the hyaline plate of the last antennal segment may be variable, but, at least in our examples, there is in *leuckarti* one prominent, deep,

rounded notch, as shown by Schmeil and Sars, and in *edax* a number of deep narrow notches (cf. figs. 3 and 12).

*Mesocyclops (Thermocyclops) tenuis* Marsh (1910)

In 1910 Marsh described and figured a new species of copepod from Calabasas, in southern Arizona, which he said resembled *C. leuckarti*, but differed "in the form of the fifth foot [the difference being apparently in the position of the inner spine, which is shown as subterminal rather than clearly on the mesial margin], in the lack of armature on the antennal segments and of serrations on the outer maxillipeds, and in the form of the receptaculum seminis." He recognized its relation to the European *oithonoides*, from which it differed in the form of the



Figures 42 and 43: *M. inversus*, Kiefer from Panama, from original drawing by Yeatman

Figure 42 End segment of endopod of fourth foot.

Figure 43. Last two segments of abdomen and furca.

fifth foot, the lack of antennal armature and the form of the seminal receptacle. The furca was described as relatively long and slender.

Lowndes (1934) recorded *tenuis* from Paraguay, but found an inconspicuous but definite hyaline plate on the 16th and the distal part of the 17th segment of the antenna. Examination of the slides of Arizona examples in our laboratory reveals indication of a slight hyaline membrane on the two terminal segments of the antenna. In these circumstances, Marsh's description of an undoubtedly valid species may be amended to include the possible presence of a poorly-developed membrane on parts of the last two segments of the first antenna.

*Mesocyclops (Thermocyclops) inversus* Kiefer (1936)

In 1913 Marsh recorded *C. tenuis* from Panama. Since that time, however, Kiefer has described a copepod from Brazil which closely approximated Marsh's

*tenuis*, but differed from it chiefly in the reverse relations of the lengths of the terminal spines of the endopod of the fourth foot, the inner spine being definitely shorter than the outer rather than longer, as in *tenuis*. In token of this difference, he gave the Brazilian copepod the name *inversus* (cf. figs. 32 and 42).

Through the courtesy of the United States National Museum and Dr. Waldo L. Schmitt, Curator of Invertebrates, we have been able to examine Marsh's slides of the Panama copepods (Nos. 3879, 3886, 3906 and 3924). Our conclusion is that, assuming the validity of Kiefer's species, the Panama copepods should be identified as *M. inversus* Kiefer.

They differ from the types of *tenuis* in that the outer terminal spine of the endopod of the fourth foot is longer than the inner; in the presence of crenulations on the outer margin of the second maxilla; in their much smaller sizes, the length of the females being 0.63 to 0.68 mm. rather than 1.1 mm.; and in the much stubbier furcal rami. They conform well with *tenuis* in the slight development of the hyaline plate on terminal segments of the antenna, and in the apparent absence of hairs on the inner margins of furcal rami.

The prominences on the connecting plate of the fourth foot are close together as in *leuckarti*, but more rounded as in *orthonoides* or *hyalinus*. In slide No. 3879 the basipod of the first foot has a seta at inner distal angle, believed to be wanting in *leuckarti*.

Kiefer (1938) from material collected in Lake Patzcuaro by Dr. Y. Matsui and sent to him by Dr. M. Sheno identified a female and a fragment as *T. inversus*. Dr. B. F. Osario Tafall of the Laboratorio de Hidrobiologia, Escuela de Ciencias Biologicas, in Mexico, has very kindly sent us a collection from that lake, in which Mr. Yeatman in our laboratory has identified both *M. edax* S. A. Forbes and *M. inversus* Kiefer. We have also had from the United States National Museum a collection of plankton taken by Hildebrand and Foster in San Salvador: this contained large numbers of *inversus*. The species may be presumed to be widely distributed in the middle American region.

#### The Genus *Mesocyclops* Sars

Copepods of this group have a generally characteristic form: the body is relatively slender and tapering, the anterior segment of the abdomen is long and not markedly wider than the following and the last thoracic segment is hardly broader than the first abdominal segment; the contour of the body is generally smooth, the segments not set off from one another at the margins (fig. 1). The furca is variable in length but with rami commonly  $2\frac{1}{2}$  to 4 times as long as wide and often definitely divergent; the lateral seta is generally placed about two-thirds of the way from base to tip of the ramus. The innermost and outermost terminal setae and the dorsal seta are relatively long.

The antennae are 17-segmented and generally with a hyaline membrane on segments 16 and 17, the membrane smooth, serrate or deeply notched.

Both rami of the first to fourth swimming feet are 3-segmented and the spine formula is 2-3-3-3; the terminal segment of the endopod of the fourth foot has two terminal spines, and the connecting plate of the fourth feet has generally,



but not in all species, a pair of sharp or rounded prominences, spinous or smooth. The fifth foot is narrow, with a seta as usual on the first segment; its second segment bears, mesial to the terminal seta, a long slender spine or spinelike seta, which may be terminal or nearly so (Kiefer's genus *Thermocyclops*) or farther up on the margin (Kiefer's limitation for *Mesocyclops*); this spine may even extend beyond the tip of the terminal seta.

The copepods of this group are, among cyclopoids, the most frequently encountered in the open waters of lakes and ponds, but they occur to some extent in smaller waters. They do not live so littorally as do most *Cyclops*, but as and commonly along with calanoids. It is noteworthy that, although the furcal armature is distinctly cyclopoid in locations and in diversity of lengths, there is evident in this group a tendency to shortening of the two apical setae (the elongate ones of *Cyclops*) and to lengthening of the innermost and outermost terminal seta and the dorsal seta, as if approaching the relative uniformity of the caudal setae as they appear in fan-like arrangement on the calanoids. This distinctive feature of structure, coupled with the distinctive habit of life, justifies Sars' separation of these copepods from other *Cyclops* in a genus of their own. Since the feeding habit and feeding structures of calanoids differ so greatly from those of cyclopoids, there is needed a comparative study of the feeding habits and the mouth-parts of *leuckarti* and its relatives.

The division of the group into two genera distinguished by so minor a difference as the exact position of the spine on the second segment of the fifth foot does not yet have sufficient justification for acceptance. As the species have been grouped by Kiefer, they differ much more within each genus than do the genera. Furthermore, the distinction between the genera does not hold if we compare drawings for the several species, such as Sars' figure for *M. [T.] oithonoides* (our figure 29) and Wierzejski's figure for *M. [M.] annulatus* (our figure 21) where the inner spine of the fifth foot is even nearer the end than it is in the former. In short, the supposed generic distinction does not apply as it is stated.

KEY TO AMERICAN SPECIES OF THE GENUS *MESOCYCLOPS* SARS (Adapted from Kiefer)

- |        |   |                      |
|--------|---|----------------------|
| 1(14)  | Fifth foot with spine on mesial side of second segment.....   | 2                    |
| 2(11)  | Connecting plate of fourth feet with a more or less prominent process on each side.....                                 | 3                    |
| 3 (4)  | Furcal rami about five times as long as broad; their inner margins with hairs   | <i>M. annulatus</i>  |
| 4 (3)  | Furcal rami not over four times as long as broad; inner margins with or without hairs.....                              | 5                    |
| 5 (6)  | Furcal rami without hairs on inner margins.....   | <i>M. leuckarti</i>  |
| 6 (5)  | Furcal rami with hairs on inner margins.....  | 7                    |
| 7(10)  | Teeth on connecting plate of P4 sharp (like <i>leuckarti</i> ).....   | 8                    |
| 8 (9)  | Seminal receptacle long, elliptical, with anterior portions scarcely developed  | <i>M. ellipticus</i> |
| 9 (8)  | Seminal receptacle with anterior portion large and recurved on each side  | <i>M. longisetus</i> |
| 10 (7) | Paired prominences on connecting plate of P4 small, rounded; anterior portion of seminal receptacle well developed..... | <i>M. edax</i>       |
| 11 (2) | Connecting plate of P4 without a prominent projection.....  | 12                   |

- 12(18) Inner terminal spine of endopodite of fourth foot little longer than outer; anterior portion of seminal receptacle recurved; inner margins of furca with hairs; terminal segments of antenna unknown..... *M. brasiliensis*
- 13(12) Inner terminal spine of endopod of fourth foot shorter than outer, or the two about equal; anterior portion of seminal receptacle little developed; inner margins of furca bare or lightly haired..... *M. meridianus*
- 14 (1) Fifth foot with inner spine apical or subapical..... 15
- 15(24) Connecting plate with small rounded unarmored prominence or without such a prominence..... 16
- 16(17) Connecting plate without process..... *M. dybowskii*
- 17(16) Connecting plate with rounded unarmored prominence..... 18
- 18(21) Dorsal furcal seta very long; almost as long as the longest terminal seta; inner margins of furcal rami without hairs..... 19
- 19(20) Inner terminal spine of endopodite of fourth foot about twice as long as outer; membrane on terminal segments of antenna poorly developed and smooth or wanting  
*M. tenuis*
- 20(19) Terminal spine of endopodite of fourth foot about equal; dorsal furcal seta almost as long as second from outermost terminal furcal seta..... *M. brehmi*
- 21(18) Dorsal furcal seta of ordinary length..... 22
- 22(23) Inner terminal spine of endopod of fourth foot shorter than outer  
*M. inversus*
- 23(22) Inner terminal spine of endopod of fourth foot five times the length of outer; the longest terminal seta expanded towards its distal end[?]..... *M. minutus*
- 24(15) Connecting plate of fourth feet with rounded spinous process on each side..... 25
- 25(26) Inner terminal spine of endopod of fourth foot about five times as long as outer terminal spine..... *M. oithonoides*
- 26(25) Inner and outer terminal spines of the endopod of the fourth foot about equal  
*M. hyalinus*

## BRIEF DIAGNOSES OF AMERICAN SPECIES OF MESOCYCLOPS

*Mesocyclops leuckarti* (Claus) 1857.

Length of female 0.9 to 1.3 mm.

Furcal rami 3 to 3½ times as long as wide, little divergent, without hairs on inner margins, lateral seta about ¼ of distance from base of ramus.

First antenna: hyaline plate on 16th and 17th segments with one deep, rounded notch, sometimes with two or three smaller notches; the remainder may be finely toothed.

First foot without seta at inner distal angle of basipod. Connecting plate of fourth foot with a prominent sharp tooth on each side; inner terminal spine on endopod of this foot somewhat shorter than outer or about equal to it. Fifth foot with inner spine seated on mesial border and shorter than the terminal seta.

Seminal receptacle T-shaped (often called "hammer-shaped"), the arms of the T (anterior portion) well developed.

Europe; Asia; Africa; Australia; North America.

*Mesocyclops edax* (S. A. Forbes) 1891.

Relatively large; length of female up to 1.5 mm.

Furcal rami about 3 times as long as wide, strongly divergent, with fine hairs in tufts on inner margins, and with lateral spine placed as in *leuckarti*.

Antenna: hyaline plate on 16th and 17th segments, with a number of sharp notches in distal half of the membrane on the 17th segment.

First foot with seta at inner distal angle of basipod. Fourth foot with small rounded prominence on connecting plate, sometimes with suggestion of a nipple-like extension; inner terminal spine of endopod shorter than outer, appearing naked under ordinary powers but showing very fine, closely set barbs with highest power. Fifth foot with spine on mesial border longer than terminal seta.

Seminal receptacle T-shaped, the anterior portion well developed.  
North America, as far south as Mexico.

*Mesocyclops annulatus* (Wiersejki) 1893.

Relatively large; female about 1.55 to 1.7 mm.

Furcal rami very elongate, *about 5 times as long as wide*, and with hairs on inner margins.

Membrane of first antenna irregularly toothed on 17th segment, smooth on 16th.

Fourth foot with inner terminal spine shorter than the outer; connecting plate shown by describer with pair of sharp prominences. Fifth foot with inner spine subterminal and longer than terminal seta.

Seminal receptacle with the anterior part scarcely developed.

Argentina, Paraguay (Kiefer).

*Mesocyclops longisetus* (Thiébaud) 1893.

Large, stout; length of female 1.6 to 2.8 mm.

Furcal rami 3 times as long as wide, with hairs on inner margins.

Hyaline plate of segment 17 of first antenna irregularly toothed or notched.

Fourth foot: the connecting plate with strong, sharp teeth, like *leuckarti*; inner terminal spine of endopod somewhat shorter than outer. Fifth foot like *leuckarti*.

Seminal receptacle T-shaped, the arms of the T (anterior portion) *large and recurved*, like that of *M. dybowskii*.

Columbia, Argentina, Paraguay. (Distribution from Kiefer, 1929, and Lowndes, 1934.)

*Mesocyclops brazilianus* (Kiefer) 1933.

Length about 1 mm.

Furcal rami about 2.7 times as long as broad, somewhat divergent, the inner margins sparsely haired; innermost terminal seta nearly three times outermost.

Antenna: terminal segments unknown.

Fourth foot: connecting plate simple, with no projection from free border; *inner terminal spine of endopod noticeably longer than outer*. Fifth foot like *leuckarti*.

Seminal receptacle much like *leuckarti*.

Brazil.

*Mesocyclops ellipticus* (Kiefer) 1936b.

Size not given.

Furcal rami slightly divergent, 3 times as long as wide, some fine hairs on distal part of inner margin; lateral seta  $\frac{1}{2}$  of the distance from base to tip of furca; innermost terminal segment at least three times outermost; dorsal seta short, about equalling outermost.

Antenna: hyaline membrane on 16th and 17th segment, that on the 17th crenate, the distal denticulations deeper than the proximal.

Fourth foot: connecting plate with sharp protuberances, like *leuckarti*; inner terminal spine of endopod equal to or little longer than outer. Fifth foot much like *leuckarti*.

Seminal receptacle *simple, elliptical* (hence the specific name), with very small lateral arms, something like those of *meridianus* and *brazilianus*.

Brazil.

*Mesocyclops meridianus* (Kiefer) 1926.

Medium-sized; length of female 1.24 to 1.42 mm.

Furcal rami about  $3\frac{1}{2}$  times as long as broad; *lateral seta proximal to middle*; inner margins of furca bare (or lightly haired?—Kiefer).

Antenna: hyaline plate small, serrated and with some small notches.

Fourth foot: *connecting plate without projecting teeth*; inner terminal spine of endopod longer than outer.

Seminal receptacle with anterior portions scarcely developed.

Paraguay (Kiefer, Lowndes, 1934), Argentina (Kiefer, 1929).

*Mesocyclops* (*Tropocyclops*) *dybowskii* (Lande) 1890.

Length 0.9–1.1 mm.

Furcal rami 8 times as long as wide (presumably no hairs on inner margins); the medial end seta not twice the outer.

Antenna: hyaline plate on 16th and 17th segments *small and smooth*.

Fourth foot: *connecting plate without projections*; inner terminal spine of endopod somewhat shorter than outer. Fifth foot like that of *oithonoides*, with inner spine apical.

Seminal receptacle like that of *oithonoides*.

Europe, North Africa, Asia; reported by E. B. Forbes (1897) as found in America in small mountain lakes of Wyoming and in a temporary pond at Urbana, Ill.

*Mesocyclops (T.) oithonoides* (Sars) 1863.

Small; length of female up to 0.9 mm.

Furcal rami  $3\frac{1}{2}$  times long as wide (presumably with no hairs on inner margins); innermost terminal seta 3 or 4 times as long as outer; dorsal seta slender and rather long.

First antenna relatively long, reaching to middle of 4th body segment; the membrane on 16th and 17th segments smooth.

Fourth foot: *connecting plate with rounded, spinous prominences*; inner terminal spine of endopod *about 5 times as long as outer*. Fifth foot with inner spine terminal, according to Kiefer, but not so shown by Sars.

Seminal receptacle much like that of *leuckarti*, the anterior portion well developed.

Europe, Asia, Africa (?), North America (?).

*Mesocyclops (T.) hyalinus* (Rehberg) 1880.

Small; length of female 0.8–0.9 mm.

Furca short, hardly  $2\frac{1}{2}$  times as long as wide (presumably no hairs).

Antenna: hyaline plate?

Fourth foot: *connecting plate with strong, spinous prominences*; inner terminal spine of endopod *about  $\frac{2}{3}$  as long as outer spine*. Spine on 5th foot shown by Kiefer as definitely terminal, almost as long as terminal seta.

Seminal receptacle T-shaped, the anterior portion well developed, like that of *oithonoides*.

Europe, Africa, Asia, Central America (Kiefer, 1929).

*Mesocyclops (T.) tenuis* (Marsh) 1909.

Length of female 1.1 mm.

Furcal rami about 3 times as long as wide, parallel, without hairs on inner margins.

Antenna: terminal segments *with incompletely developed hyaline plate*. Lowndes says of the copepods taken in Paraguay and identified as *M. tenuis*: "The last two joints bear a very definite hyaline membrane. This membrane extends the whole length of the 16th segment, but is not to be traced in the proximal half of the 17th segment".

Fourth foot: *Connecting plate with small, rounded, smooth prominences*; inner terminal spine of endopod *curved and about twice the length of the outer*. Fifth foot with outer spine subterminal.

Seminal receptacle peculiar; see figure.

North America (Arizona—Marsh), Paraguay (Lowndes, 1934).

*Mesocyclops (T.) brehmi* (Kiefer) 1927a.

Length of female about 1 mm.

Furcal rami strongly divergent, about 4 times as long as wide; no hairs; innermost terminal seta *almost as long as the outer of the 2 well-developed apical seta*; dorsal seta *almost as long*; lateral seta about midway of outer margin.

Antenna: hyaline plate on 16th and 17th segments very small and smooth or perhaps very finely serrate.

Fourth foot: *connecting plate with weak, unarmed prominences*; terminal spines of endopod thin and about equal. Fifth foot with spine terminal, stout and somewhat shorter than apical seta.

Seminal receptacle not fully described.

Uruguay.

*Mesocyclops (T.) minutus* (Lowndes) 1934.

Very small; length of female 0.6 to 0.65 mm.

Furcal rami about parallel, 2 to 3 times as long as wide; *very short terminal seta* ("quite characteristic", Lowndes); inner of the two well-developed terminal (apical) setae expanded in its distal end (but not so shown by Kiefer for Brazilian examples).

Antenna: hyaline membrane on 17th segment smooth (not seen on 16th segment); 16th segment longer than 17th.

Fourth foot: connecting plate with smooth prominences not widely separated (see Kiefer's figure, 1936); *inner terminal spine of endopod about six times as long as outer*, conspicuously bent. Fifth foot with second segment very long and slender, inner spine terminal and about equalling terminal seta.

Seminal receptacle T-shaped, with an anterior mesial extension besides the well-developed arms.

Paraguay (Lowndes, 1934), Brazil (Kiefer, 1936).

*Mesocyclops (T.) inversus* Kiefer, 1936a.

Small; length 0.68 to 0.70. Lateral angles of last thoracic segment somewhat produced.

Furcal rami slightly divergent,  $2\frac{1}{2}$  times as long as wide; lateral seta placed clearly proximal to middle of outer margin (presumably no hairs).

Fourth foot: connecting plate with small, smooth prominences on each side; inner terminal spine of endopod  $\frac{1}{2}$  the length of the outer. Fifth foot not described, but, presumably, with spine terminal or nearly so.

Anterior and posterior portions of seminal receptacle form a long, elliptical structure from which small lateral canals lead to the sides.

This copepod is said by Kiefer to be much like *tenuis*, but with the reversed relations of lengths of spines on the endopod of the fourth foot, hence the name *inversus*. Through the courtesy of the United States National Museum and Dr. Waldo L. Schmitt, Curator of Invertebrates, we have recently been able to examine slides of *tenuis* from Arizona and slides of copepods from Panama labeled *C. tenuis*. The latter differ from the type and correspond with Kiefer's description of *inversus*; if, then, the latter is a valid species, it rather than *tenuis* may now be credited to Panama.

Brazil, Panama, San Salvador, Mexico.

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# A GASOMETRIC PIPETTE FOR THE STUDY OF RESPIRATORY GASES

By F. H. McCutcheon

## TEXT FIGURE 1

A modification of a standard liquid measuring pipette has been developed as an improvement over devices such as the Hempel burette for gas analysis. It has proved useful for laboratory teaching of respiratory physiology and for routine analyses of gas mixtures. It lacks the fine precision of the usual Haldane apparatus, but it has certain advantages in cost, simplicity and rapidity of operation, ease of maintenance, and measurement of small residues of gas. As described, the maximum overall precision is about 0.2 per cent which is sufficient for many types of measurement. The precision can be increased by using smaller pipettes.

The complete pipette assembly (Fig. 1-B) can be made of pyrex by any competent glassblower<sup>1</sup> at a cost of less than ten dollars. The syringe adapter<sup>2</sup> (Fig. 1-A) allows a standard Luer type syringe to be used for quickly measuring and delivering a gas sample without temperature interference due to direct handling. It is easily made from two, three-quarter inch thick, wood blocks clamped together for shaping and drilling.

In making analyses two alternative procedures may be used. The first to be described, in which the sample is measured in the syringe, is most useful when many repeated analyses are to be made with large volumes of gas available. Samples can be measured in the syringe if the syringe is first calibrated against the pipette. This calibration can be done by measuring a sample from the syringe in the pipette filled with water. The water must be at room temperature and saturated with air. It can also be done by analysis of room air for oxygen since the trace (0.03% in a well ventilated room) of CO<sub>2</sub> is negligible in the apparatus. The latter analysis will be described, because it typifies the procedure for all types of analyses.

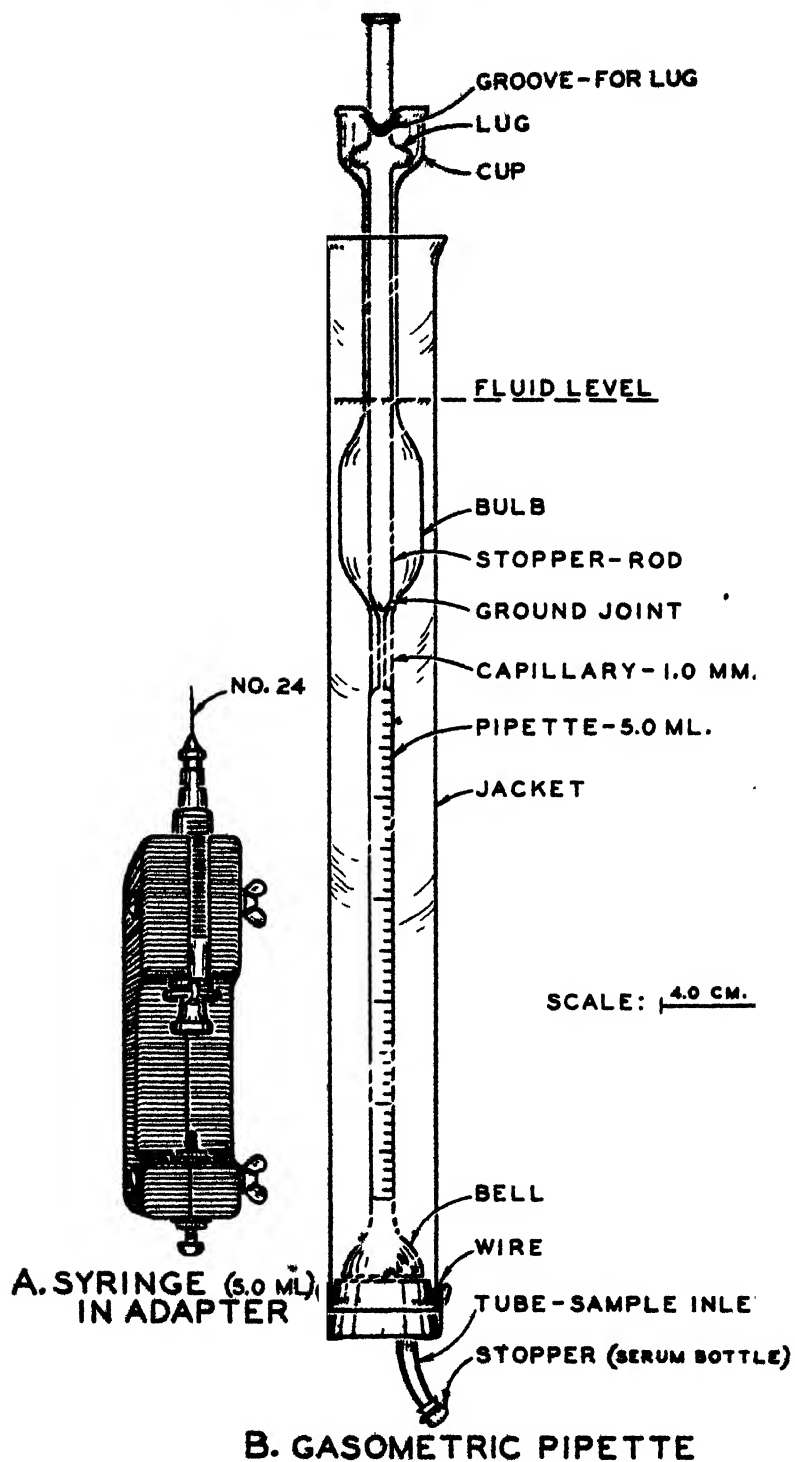
Fill the jacket to the level indicated on Figure 1 with water (about 300 ml.). Pour the water into a beaker containing 4.5 gr. of KOH. Drop 10.0 gr. Na<sub>2</sub>S<sub>2</sub>O<sub>4</sub> (sodium hydrosulphite) into the jacket and pour back the KOH solution. Lower the pipette into the jacket with its stopper closed and mix the hydrosulphite in the bottom of the jacket. Some undissolved hydrosulphite in the inlet tube is not objectionable. Place the stopper lugs in the grooves and allow the concentrated solution to fill the bulb, then lower the stopper to close the pipette. By the time analysis is to be made the solution should be at room temperature.

Adjust the set-screw on the syringe adapter until the plunger, when touching

<sup>1</sup> The pipette assembly described in this report was made by Mr. D. E. Sampson of the University of North Carolina. Duplicates can be obtained by writing the Scientific Supply Room, University of North Carolina, Chapel Hill.

<sup>2</sup> The value of a syringe employed in this manner was brought to my attention by the work of Dr. P. F. Scholander, Swarthmore College.





it, shows a reading of 5.0 ml. on the syringe calibrations. When a sample of room air has been analyzed it may indicate the necessity for slight readjustment of the set-screw so the syringe will deliver exactly 5.0 ml. as measured in the pipette (21.0%  $O_2$  = pipette reading 3.95 ml. residue after  $O_2$  absorption). For analysis, the sample is delivered into the bell through the rubber stopper on the inlet tube. If a few small bubbles form during delivery of the sample they can easily be made to fuse again with the main bubble during the absorption procedure which follows. The single large bubble which usually forms may, stay in the bell until the jacket is tapped with the finger to start it rising in the pipette.

When the bubble reaches the bottom of the capillary, the pipette is raised about half-way out of the jacket to put the sample under less pressure relative to the bulb. The stopper is then raised slightly, and about one half of the hydro-sulphite solution in the bulb is allowed to drain slowly through the sample. Any small bubbles will join the main sample, and surface tension will hold the large bubble in the pipette and out of the capillary. The stopper is then closed, and the pipette is immersed to the capillary and allowed to drain for at least one minute. The bottom meniscus of the sample is next brought to the level of the fluid in the jacket (atmospheric pressure), and the volume (air minus oxygen) is read. This reading should be taken at once, because evaporation from the outer surface of the pipette will gradually introduce a temperature error. As a check for complete absorption, allow about one-half the remaining solution in the bulb to run through the sample. When measuring unknown samples for oxygen, the analysis of room air should be made occasionally to check the apparatus. When this check reading does not duplicate the first, a fresh solution is required. A number of analyses can be made before replacing absorbing solutions. The procedure for measuring  $CO_2$  is the same as for  $O_2$  except that sodium hydrosulphite is omitted. In all cases, the syringe should be rinsed with slightly acidulated water (neutral red indicator) and clear water after each sample is delivered.

For repeated analysis of mixtures of gases (e.g. alveolar air) two jackets are convenient, one with KOH alone for  $CO_2$  absorption and the other with the solution for  $O_2$  absorption. From such a composite gas, the sample is first analyzed for  $CO_2$ . The pipette is then transferred to the other jacket and a second sample is introduced from which  $CO_2$  and  $O_2$  will be absorbed simultaneously. A simple calculation gives the differential analysis. The pipette must be rinsed with water before it is returned to the KOH solution.

It is evident that when a sample is measured in the syringe care must be taken that its temperature is the same as that in the pipette (i.e. room temp.). Also the source of the sample must be at atmospheric pressure or higher when the needle is withdrawn or contamination with room air will result.

The second alternative procedure, which is especially useful where only small samples are available, is to make initial readings and differential absorption all

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Figure 1.—Details of apparatus for gas analysis. A support stand and clamp to hold the pipette assembly are omitted from the diagram.

on one sample within the pipette. In this case the sample is introduced into the pipette in the presence of slightly acidulated water (i.e. 2 drops of lactic acid with a drop of neutral red indicator). A reading is taken as previously described, which gives the initial volume. Then KOH solution (5%) at room temperature is poured into the cup and allowed to drain into the bulb which was left nearly empty when the sample was introduced. The  $\text{CO}_2$  is absorbed from the sample and the residue measured. Next a few grams of sodium hydrosulphite are dissolved in about 20 ml. of 5% KOH solution and introduced into the bulb in such a way as to insure minimum exposure to air. If some undissolved hydrosulphite is washed into the bulb the most satisfactory absorbent will be assured. Experience will indicate the amount necessary to obtain constant readings for oxygen absorption. Because fresh solutions are required for each analysis in this latter procedure, it is slower than the former when repeated analyses are to be made.

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# ESSENTIAL AND STRATEGIC MINERALS OF SOUTHEASTERN UNITED STATES

By W. F. PROUTY

That nation or group of nations which controls the world's mineral resources and uses them to the best advantage will be the winner in any war.

In the past, only a few minerals were essential for war. The struggle between Germany and France in past wars has been largely for the control of coal and iron lands. Present mechanized warfare demands not iron or steel but many varieties of alloyed steel and varieties of metals and alloyed metals each for its particular use. With high temperature tool-steel-alloy the production of turned metal articles, such as shells, can be greatly accelerated. If we have an insufficient amount of any very essential mineral, we speak of this mineral as a critical mineral. No nation possesses a sufficient amount of all the essential minerals or materials and therefore has a critical mineral list.

Before World War II Great Britain and the U. S. together controlled about 75% of the world's mineral production.

Thus far in the war the Axis has increased its control over some of the more important minerals as follows (according to J. H. McGraw, Feb. 1943 No. of Engineering and Mining Journal):

- Iron from 6% to 46%
- Steel production from 20 to 34%
- Petroleum from 1 to 7%
- Coal from 27 to 53%
- Copper from 5 to 10%
- Lead from 7 to 22%
- Zinc from 16 to 27%
- Tin from 1 to 72%
- Manganese from 2 to 30%
- Chrome from 3 to 30%
- Tungsten from 6 to 60%

By greatly stepping up domestic production, locating new deposits, and utilizing its neighbors resources, the Allies can still out-produce the Axis in *most* of the essential minerals.

The present United States production of coal, iron, steel, copper, zinc, mercury, manganese, chromium, tungsten, and antimony is breaking all records. The production of coal in 1943 will probably be about twice that for 1939. Aluminum has already exceeded a sevenfold pre-war production and is gaining by leaps and bounds, and magnesium plants now nearing completion will yield more than 100-fold the pre-war production.

It will be interesting, I think, to examine the southeastern United States in respect to its essential and critical minerals and its contribution to the war effort. The southeastern United States is that part lying south of the 39.5° parallel and east of the 100° meridian.


This area has the best and most productive coal field in the world, extending from the Mason-Dixon line on the northeast to central Alabama, thence through the Ouachita Region and in Texas. West Virginia alone in 1941, furnished more than 25% of the United States bituminous coal production. Much of the coal of this area moves by cheap transportation on the Ohio, Mississippi, Tombigbee, Tennessee, and other rivers and much also on trunk-line railroads. Some goes to both Atlantic and Gulf ports: such as Philadelphia, Baltimore, Norfolk, Charleston, Savannah, Pensacola, Mobile, New Orleans, and Houston. These coal fields are amply supplying the varied and rapidly developing industrial needs of the southeastern United States as well as the power needs of much of the bordering region and also furnishing high-rank bunker-coal for various shipping lines, and for export.

The southeastern United States has the greatest petroleum and natural gas producing area in the world. About 75% of the United States production comes from this region. The rush for aviation supremacy has given added zest to chemical research in petroleum which, in turn, has now given us a super 100 octane gasoline and superior lubricating oils. War emergency transportation has also yielded a great network of pipelines for oil and gas transportation in this area and from this area to much of the northeastern United States.

The southeastern United States furnishes normally about 95% of the United States phosphate production, largely from Florida and Tennessee, which is about  $\frac{1}{3}$  the world production in peace times and about  $\frac{1}{2}$  at the present time. A considerable amount of the phosphate is being turned into super-phosphate by the use of low cost T. V. A. electricity. This greatly reduces the shipping cost per unit-fertilizing efficiency.

The United States produces  $\frac{1}{2}$  of the world's sulphur (well over 3 million long tons annually). Most of this comes from the great salt dome areas in Louisiana and Texas. This cheap sulphur, together with much pyrite especially from Tennessee and Virginia, gives an abundance of cheap sulphuric acid for industrial uses. Industrial progress is directly proportional to the use of sulphuric acid. Locally produced bi-product ammonia from bi-product coke ovens combined with locally produced sulphuric acid and phosphate, makes the southeastern states the greatest fertilizer *producing* as well as fertilizer *using* area of the world.

The United States produces about 38% of the world's zinc and about 23% of the world's lead. Of the United States production about 50% of the zinc and 45% of the lead comes from the southeastern United States. In order of their importance as *Zinc* producing areas the states are: Oklahoma, Kansas, Tennessee, Missouri, Kentucky, Virginia. In order of importance for *Lead* production we have: Missouri, Oklahoma, Kansas, Southern Illinois, Virginia, Tennessee, Kentucky.

The United States produces 60% of the world's fluorspar and about 70% of this comes from the southeastern states chiefly from the southwestern Kentucky and southeastern Illinois area. The government is hunting for new deposits to keep pace with the rapid increase in the production of basic open hearth steel, electric-furnace steel, undry steel, ferro-alloys, hydrofluoric acid to use in mak-

ing artificial cryolite for electric furnace flux in aluminum making, and many other industrial purposes. The importance of fluorspar in the war effort is illustrated by the fact that every flying fortress represents the consumption of 1,500 lbs. of fluorspar.

The United States has furnished about 10% of the world's normal aluminum ore (bauxite). Allied countries normally supply about 41% of the world's bauxite production. United States production is entirely from the southeastern states, chiefly Arkansas (92%)—Georgia, Alabama, and Virginia (8%). There has been, in the past few months, greatly increased production from both Arkansas and Georgia and new deposits discovered in Alabama. One of the new aluminum plants is designed for the direct reduction of aluminum from bauxite. It does not require previous chemical conversion to alumina as do the old plants. Large quantities of high alumina clays (bauxite clay) as well as kyanite, already blocked out in the southern states, may soon be used for aluminum manufacture. Five tons of bauxite require 7 tons of other materials to produce 1 ton of aluminum. These other materials are: coal, limestone, salt, by-product carbon, and either artificial or natural cryolite. All these except natural cryolite, which it is difficult to ship from Greenland at the present, are furnished in the S. E. states. Practically all of the imported bauxite comes from Dutch Guiana (Surinam) and from British Guiana. Both of these areas are, in peace time, conveniently located in respect to Mobile, New Orleans, and St. Louis. It is difficult to realize the rapidity of growth of the aluminum industry. This growth has been made possible by the recent great development of water power and auxiliary steam power in the southern Appalachians. At Alcoa, Tennessee, is located the largest aluminum plant in the world. Several other large aluminum plants are scattered about the country, including our own plant at Baden, N. C., and the recently opened Lesterhill plant near Sheffield and Wilson Dam, Alabama.

Most of the high quality clays of the United States are found in the southeastern section of the United States. Residual high grade white clays or kaolins are most abundant in North Carolina. The sedimentary white clays occur mostly in South Carolina and Georgia along the inner edge of the Coastal Plain. The very important, white-burning, ball clays come chiefly from Tennessee, Kentucky, and Florida. Since World War I these domestic clays have been gradually replacing the high grade English clays, once thought essential.

The United States has long lead the world in iron and steel production. The greatest contributing factor in this production has been the vast open pit iron ranges of the Lake Superior area and the cheap lake transportation. In competition with the lake area there has grown up in the southern states a great iron and steel industry centering in the Birmingham District, which is located toward the southern end of the Appalachian coal field. There is probably no other place in the world where raw materials for steel manufacture are as conveniently and economically located. Here we have vast quantities of sedimentary hematites, abundant manganiferous limonite, high grade coal and flux, good climate, and abundant and cheap labor. The continued growth of steel manufacture in the South is assured by the rapid industrialization of the area, the decreasing reserve

of Lake ores, the recently acquired success in beneficiation of low grade Clinton ores, and the increasing use of high grade Brazilian, Venezuelan, Cuban, Chilean, and Texas ores.

Flake graphite used chiefly in the manufacture of crucibles for crucible steel making, normally comes largely from Ceylon and Madagascar. During a war, this source is mostly cut off. Toward the end of World War I, Alabama was producing over 60% of the domestic graphite flake. Recently new methods of concentration have nearly doubled the percentage of recovery of graphite flake from these ores with this new incentive. The Alabama area is now being reopened for emergency production as is also the Texas area.

The Southern Appalachians Region has for many years lead the United States in mica production although it could never supply the large and growing demand in competition with shipments from India and elsewhere. With decreased foreign shipments, sheet mica has become a critical mineral. It is indispensable for use in the vast numbers of condensers and other electrical equipment used in our mobile units on land, sea, and in the air. The southeastern states especially North Carolina, South Carolina, Georgia, Virginia, and Alabama, are speeding up production to help meet the demand.

I cannot take the time to discuss adequately many of the minor essential or critical minerals being supplied in the South at the present time. The titanium-bearing minerals, rutile and ilmenite, are now being secured in large quantities from the Nelsonite deposits in Virginia and from ancient sea sands in Florida. Lithium compounds have become strategic materials in a number of new and important ways. South Dakota and North Carolina have been the two states producing spodumene, the most important lithium mineral. A large plant for the production of spodumene is nearing completion at Kings Mt., N.C. This locality has one of the largest and best spodumene deposits known.

Tungsten is another strategic material. World production of tungsten has been largely from southeastern Asia. Many small deposits in the United States are coming into production including that from a newly discovered and promising area in Vance Co., N. C. The southeastern states are making large contributions in the production of many additional *essential* and *strategic* minerals, such as salt, gypsum, bromine, barite, celestite, ocher, manganese ores, magnesium minerals, metallic magnesium, talc, pyrophyllite, kyanite, feldspar, zircon, asbestos, copper ores, quartz crystals, vermiculite, gold, natural abrasives, helium, arsenic, cadmium, mercury, and many others. The southeastern United States also leads in the production of at least one half of the above mentioned minerals and materials.

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## BASIC WILDLIFE CONSERVATION

By ROSS O. STEVENS

The wildlife resources of North Carolina and a large majority of the other states are passing through a very critical period. What happens to these resources during the remainder of the war and for the first few years thereafter will be important. Activities during this period will determine largely the extent to which the wildlife resources will play the important part they should play in the scheme of future living in this country. My purpose here is to point out what the critical condition is, why it exists, and to some extent what will be necessary to bring about improvements.

Previous to the first World War, very little attention had been given to the scientific management of game and fish, and practically none to other forms of wildlife. Increased hunting and fishing pressure following the war with the resultant downward trend in game and fish populations caused sporadic attempts to improve wildlife conservation programs. Not until 1924, however, did Herbert L. Stoddard begin the now famous study of the bobwhite quail on the private quail preserves of the southeastern states. This study was carried to completion in 1929, and the published report<sup>1</sup> still forms the basis for much of the field management of game throughout the country. W. L. McAtee of the U. S. Bureau of Biological Survey (now U. S. Fish and Wildlife Service) technically supervised this project. It is important to remember, in view of some points which will be mentioned later, that Stoddard's work was financed largely by wealthy sportsmen, owners of the quail preserves, and not by governmental appropriation.

In 1928 and 1929 and thereafter, game fact-finding projects were set up in various parts of the country. Ralph T. King studied the ruffed grouse in Minnesota; Paul Errington, the bobwhite quail in Iowa; Gorsuch, the Gambel quail in Arizona; Yeatter, the Hungarian partridge in northern Ohio and southern Michigan. By late 1934 nearly all of these studies had been terminated with varying degrees of completeness. These projects were financed and administered cooperatively by sporting arms and ammunition industries, state game departments, state colleges and universities, and the U. S. Biological Survey. In 1930 the U. S. Biological Survey, the American Game Institute, state game departments, and land owners cooperated in establishing several upland game management demonstrations. These projects were located in states from Indiana to Texas and eastward. They were financed largely by the individual state game departments concerned and to a lesser extent by the sporting arms and ammunition industries through the American Game Institute, and by private individuals. Many of these projects passed out of existence within two years of their inception. All except one or two were terminated by July, 1933.

All of these early game projects had two important purposes. Their sponsors

<sup>1</sup> *The Bobwhite Quail, Its Habits, Preservation and Increase*, by Herbert L. Stoddard, Chas. Scribner's Sons, N. Y., 1932.



were hopeful of obtaining badly needed facts upon which to base better game management. Primarily, however, the purpose of these initial projects was to create an interest on the part of the state game departments to carry on wildlife research and experimental work, and to improve game and fish administration.

In 1934, due in some degree to readily available relief funds, game and fish projects of all types began to appear, and since that time dozens upon dozens of these projects have come into existence. In spite of this fact, however, the necessary data for instituting sound wildlife administration and management have not been secured. A primary reason for this has been that large numbers of these projects have been terminated before their intended goals have been reached.

It has been my privilege to be closely associated with the problems involved in these fact-finding attempts for many years. My first direct contact therewith involved the upland game management demonstrations which were begun in 1930. From experiences with these early projects, and through the decade since their termination, two important reasons for failure of many game and fish projects have been outstanding. Seven states were directly involved in the 1930-1933 demonstrations. Since 1933 my activities have permitted me to become familiar with game and fish affairs in at least ten additional states. The programs of all the states have been studied and observed closely for many years. These statements are given as a basis for following remarks concerning the two reasons for failure of so much wildlife work.

The first reason centers around inadequacy of personnel. The second involves the lack of continuity of game and fish administrative programs.

In the late nineteen twenties, a few universities and colleges established curricula in game and fish management. Since 1930 several other schools have instituted courses in wildlife conservation. The boom in wildlife field work which followed the last economic depression came before the educational institutions could train a sufficient number of qualified game and fish technicians. During the post-depression period, there was much switching and transferring of personnel. The wildlife field seems to have taken on more than its fair share of those who did not survive in other activities. Because of the below-average qualifications of many of these men, the type of research and management work conducted was of doubtful quality in many instances.

Projects illustrating this point could have been found in nearly every part of the country. A typical example involves a study of the causes of destruction of bobwhite quail nests on a Federal Resettlement Administration project in a southern state several years ago. In one season an investigator on this project secured what he called "sufficient information" to place the common box turtle, *Terrapene carolina*, near the head of the list of destroyers of quail nests. Regardless of the fact that after several years of careful study and experimentation, Stoddard had given this little reptile a clean slate as far as being an enemy of quail was concerned, this young investigator prepared a sworn statement giving the box turtle the status of an important destroyer of quail nests. Mainly his conclusions were based on three observations as follows: One turtle was found about a yard from a quail's nest and a second turtle was observed coming in the direction of the first. The conclusion was that both were heading straight for the quail's

nest for the purpose of destroying it. Apparently no thought was given to the fact that this observation was made during the breeding season of the turtles. The second recorded observation stated that a turtle was found in a quail's nest with some of the quail eggs broken. A third observation was made wherein a box turtle was found near a quail nest from which some of the eggs had disappeared. In all three cases the turtles were killed, but internal examinations were not made. Thereby, any worthwhile evidence which might have been available was destroyed. The only claim that this gentleman had of being qualified to carry on wildlife research work at that time was that for several years he had served as a federal prohibition agent in the southern mountains.

Of course, not all the people who switched to wildlife were poorly qualified, or so badly misled. Many of them, as well as many of those who have been trained in game and fish management in our colleges and universities, will admit their failure to perform to the best of their ability, but they attempt to keep their work going, hoping that conditions will improve.

In a large majority of cases the reason for not being able to carry out good work goes back to the second point mentioned previously. That is the lack of continuity of wildlife management and administrative programs.

One reason why the upland game management demonstrations could not make more progress in the early 1930's was that too frequently by the time a project was set up and put in good running order, a new state administration would be elected, and the old administrative group with all of its belongings, including game and fish activities, regardless of quality, would be eliminated. My review of the literature has convinced me that this periodic changing of wildlife administrative practices, policies, and personnel was very much the rule previous to 1930; also, with comparatively few exceptions, this rule still holds. Even though the untrained man who is appointed as game and fish administrator under such a set-up has a real desire to do a good job, he is faced with the necessity of stepping aside by the time he becomes familiar with even the most rudimentary principles. A new man takes his place to repeat the procedure, and so on. Ordinarily under such conditions the wildlife resources continue to fare badly.

Because of the unequal ability of individuals to administer the wildlife resources you would expect almost constantly changing conditions. This is quite true. In the evolution of game and fish departments the states have gone through, or are involved in the process of going through four rather distinct stages. Possibly as many as ten states are still in the first stage. Thirty states or more are in the second stage. It is very doubtful that more than eight states have reached stages three and four, which in principle, are closely related.

Surprisingly enough, some of the game and fish departments which have been intact continuously for a great many years, are found in the first stage. The two main functions of the game and fish departments in these states are the collection of license revenues and the practicing of small amounts of inefficient law enforcement work. As far as wildlife conservation is concerned, these game and fish departments are very ineffective. Two reasons for the existence of such conditions stand out. In some instances, the people of the states concerned have not come to realize sufficiently the value of the wildlife resources. The desire to

have improved conditions has not developed. In other states, the chief game and fish administrative officials have, through their game and fish warden service and otherwise, built such strong political organizations that it has been impossible to dislodge them. Eventually these states will emerge from this condition.

The wildlife programs of states in the second stage have many common characteristics. A large number of people in these states have come to realize the importance of the wildlife resources and of having sound wildlife administration. Frequently, however, there is lack of agreement as to what constitutes a sound program. Generally the wildlife interests are unorganized. Their enthusiasm is sporadic. On the other hand, the tendency to use the wildlife resources for political purposes has remained strong and well organized. The result, generally speaking, is a cyclic type of wildlife program. When the game and fish program in a state reaches a low ebb and the license revenues dwindle, the sportsmen become actively interested. At this point, when the money involved is insignificant, the sportsmen only are interested. Often under such conditions, men are employed as game and fish administrators who really have a desire to bring about sound wildlife conservation. They work hard and conscientiously. Increased effort is rewarded with increased license revenue. More money means there can be better law enforcement, improved wildlife research, education, and administration. All looks well and the sportsmen's interest tends to subside. As the game and fish fund grows, it gradually becomes more conspicuous. A new administration makes its appearance and new personnel takes over the game and fish department. Regardless of how good the preceding program might have been, it is greatly curtailed or eliminated. License funds eventually drop off, and finally the cycle starts all over again.

Under conditions which make for this sort of procedure, it would be utterly impossible for each new game and fish administrator to accept the activities which were started by his predecessor, because of the possibility that the people might refer to the program as belonging to the previous game and fish administrator. This would not gain support for the new group.

The lack of continuity of programs in those states of the second stage is due primarily to one thing. Nearly every difficulty, whether it concerns wildlife research, education, law enforcement, or administration, can be traced back to one factor:—The lack of sound basic laws upon which sound programs can be based; laws which will permit development of the wildlife resources for the benefit of all the people; laws which will make it possible to remove the wildlife resources from the realm of vote-getting political activity. This is an important point to remember.

In many instances the basic laws of the wildlife resources departments in the states of the second and third stages are similar. In the third group the wildlife resources are generally administered by a commission or board, the members of which are appointed on a staggered basis so that ordinarily no governor appoints a majority of the board members during a single term to office. This body chooses its own leaders and paid personnel, and is responsible administratively for the execution of the wildlife program. In many of the second stage states a commission or board is appointed also, but if the basic laws are examined care-

fully loop-holes will be found either in the method of choosing members of the governing body, in the length of term of office of these members, or in the method of selecting the chief wildlife administrative officials or a combination of these to permit political dictation. As long as this possibility exists wildlife programs cannot progress satisfactorily.

The fourth type of wildlife program has the desirable features of the third type, but is strengthened by virtue of the fact that the organization is based on an amendment to the state constitution, meaning that the system cannot be changed unless by vote the people eliminate or change the amendment.

Before any of the improved types of wildlife administration can come into and remain in existence, there must be a greater understanding and appreciation of the problems by the public so that public support will be forthcoming. The sportsmen who hunt and fish, the naturalists, educators, those interested in research and many other groups, have a stake in the wildlife resources. My hope is that the North Carolina Academy of Science will continue its active interest in improving the status of the wildlife resources in this state.

This is an opportune time to give thought to wildlife problems. There is reason to believe that wildlife work will expand rapidly after the war. Plans are already underway for this expansion. In my opinion, we are not and will not be ready for this expansion. There is grave danger of falling back into the same problems that developed during the post-depression period and into the turning out of inferior work. This could be prevented by taking advantage of every opportunity now to secure facts upon which the successful completion of such work must be based.

Ten years ago many technical wildlife conservationists were critical of having so many wildlife fact-finding projects begun and terminated before completion. My thoughts were directly opposed to such activities. Yet since coming back to North Carolina in 1937 my efforts helped to start the North Carolina Cooperative Farm Game Program, the farm game research projects, the study of the furbearers of North Carolina, and a study of the Virginia White-tail deer. All of these projects were terminated before their objectives were realized. The recent session of the North Carolina General Assembly passed a law including an appropriation of \$200,000 to supplement the budget of the North Carolina Division of Game and Inland Fisheries for the next biennium. The law specifically states, however, that none of this money can be used until all research projects in the Division of Game and Inland Fisheries have been eliminated. This, in spite of our very limited knowledge of the state's wildlife, and in spite of the anticipated expansion of game and fish conservation activities after the war. For all these things some people want to criticize individuals involved, but this is not right. These individuals are working under a system which we the people make available for them. If the system will not permit development of a sound wildlife program, the solution lies with all the people and not with the individuals directly concerned.



